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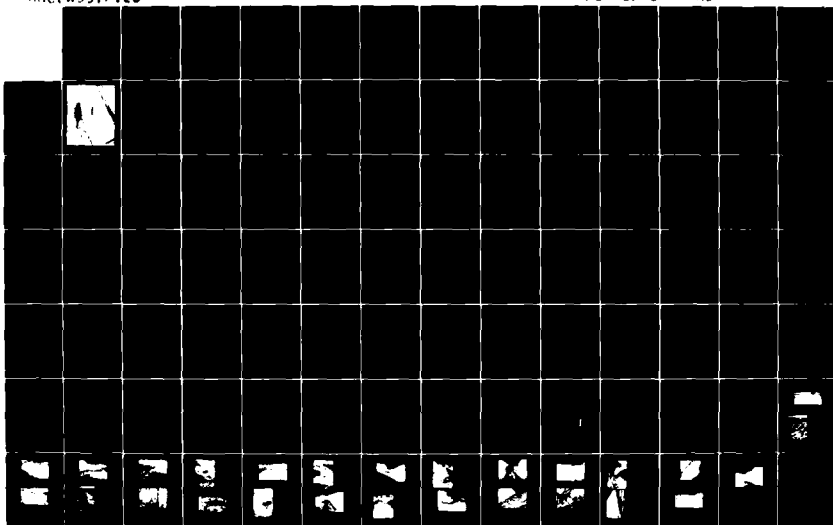
NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
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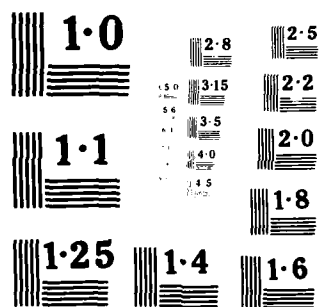
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MASSACHUSETTS COASTAL AREA
WESTON, MASSACHUSETTS

NORUMBEGA RESERVOIR DAM AND DIKES
NORUMBEGA RESERVOIR DAM AND EAST DIKE MA 00782
DIKE 2 AND DIKE 3 _____ MA 01208
DIKE 4 _____ MA 01209

**PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM**



SELECTED
JUN 24 1985
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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASS. 02154

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MA 00782/01208/01209	2. GOVT ACCESSION NO. AD-A155742	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Norumbega Reservoir Dam and Dikes Dike 2, 3, and 4 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS	5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT	
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	8. CONTRACT OR GRANT NUMBER(s)	
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12. REPORT DATE March 1980	
	13. NUMBER OF PAGES 90	
	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
	16a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DAMS, INSPECTION, DAM SAFETY, Massachusetts Coastal Area Weston, Massachusetts Seaverns Brook		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The main dam is about 1100 ft. long and 25 ft. high. Dike 2 has a length of 310 ft. The third dike has a length of 500 ft. and dike 4 has a length of 700 ft. All three dikes have a maximum height of about 15 ft. The visual inspection indicated that the dam and dikes are generally in good condition. The reservoir has a small size classification and high hazard potential.		



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
424 TRAFALGAR ROAD
WALTHAM, MASSACHUSETTS 02154

NEDED

JUN 30 1980

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

Inclosed is a copy of the Norumbega Reservoir Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, MDC, Boston, Massachusetts.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely,


MAX B. SCHEIDER

Colonel, Corps of Engineers
Division Engineer

Incl
As stated

NATIONAL DAM INSPECTION PROGRAM

PHASE I INVESTIGATION REPORT

BRIEF ASSESSMENT

Inventory No.: Main Dam & East Dike, MA 00782;
Dikes 2 & 3, MA 01208; Dike 4, MA 01209
Name: Norumbega Reservoir Dam and Dikes
Town: Weston
Stream: Seaverns Brook
Date of Inspection: October 30, 1979

Norumbega Reservoir is part of the MDC Hultman Aqueduct water supply system. The main dam is comprised of a 1,100 foot long, 25 foot high main embankment, and a 1,200 foot, 10 foot high east dike. There are also 3 separate earth dikes designated dikes 2, 3 and 4. Dike 2 has a length of 310 feet. Dike 3 has a length of 500 feet and Dike 4 has a length of 700 feet. All three dikes have maximum hydraulic heights of approximately 13 feet. Directly north of the main dam is the MDC's Schencks Pond. (See Report MA 00784). There was no indepth engineering data provided. Therefore, the adequacy of the dam and dikes were primarily evaluated by the visual inspection, past performance history, the available as-built drawings and sound engineering judgement. The visual inspection indicated the dam and dikes to be in generally good condition.

Norumbega Reservoir has a small size classification and high hazard potential. Based upon Corps Guidelines the full

Norumbega Reservoir Dam : Dikes

PMF was analyzed. The test flood inflow from the 0.10 s.m. drainage area is 300 cfs. The storage capacity of the reservoir is enough to retain the entire test inflow considering the initial reservoir level to be the normal surface elevation of 269 \pm .

With the intital water surface level at 271.4 \pm , spillway crest, the test flood would surcharge the reservoir to elevation 272.8 \pm . The test flood outflow is 150 \pm cfs. The spillway is surcharged 1.4 \pm feet. At the top of dam, elevation 274.4, the spillway has a discharge capacity of 500 \pm cfs.

The dam and dikes are in generally good condition. However, due to excessive growth of brush and trees on the slopes and the lack of seismic stability investigation, the dam and dikes are rated fair. It is recommended that the Owner engage a qualified registered professional engineer to assist with developing means for removing trees and roots from the dam and dikes and selecting acceptable backfill for holes caused by root removal and investigating the dam for seismic stability.

Furthermore, the Owner should institute certain remedial measures including repair and prevention of slope erosion near the gatehouse; removal of brush and tree growth on the slopes and spillway channel floor; establishment of a formal warning system for notifying downstream areas in event of an emergency; a formal emergency operational procedure for the personnel with this procedure kept at the gatehouse and inspection of the dam and dikes every year at both high and low reservoir levels.

These above recommendations and remedial measures, should be implemented by the Owner within one year after receipt of this Phase I Inspection Report.



Ronald H. Cheney

Ronald H. Cheney
Vice President

Hayden, Harding & Buchanan, Inc.
Boston, Massachusetts

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This Phase I Inspection Report on Norumbega Reservoir Dam and Dikes has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Aramast Mahtesian

ARAMAST MAHTESIAN, MEMBER
Geotechnical Engineering Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Richard J. DiBuono

RICHARD DIBUONO, CHAIRMAN
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to

assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

The Phase I Investigation does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

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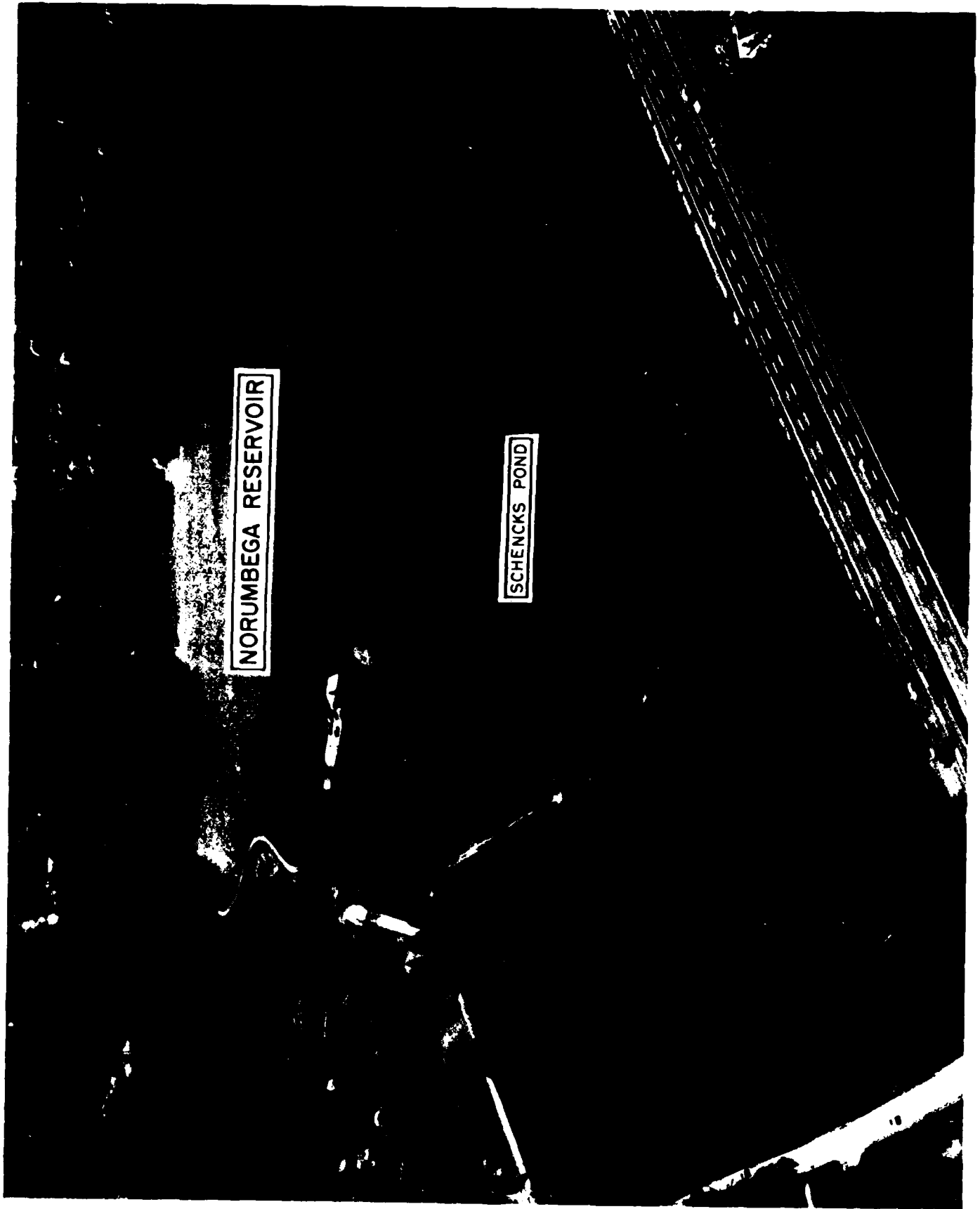
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PHASE I
NATIONAL DAM INSPECTION PROGRAM

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Hayden, Harding & Buchanan, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued Hayden, Harding & Buchanan, Inc. under a letter of 24 October 1979 from William E. Hodgson Jr., Colonel, Corps of Engineers. Contract No. DACW 33-80-C-0006 has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.

(3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location

Norumbega Reservoir Dam is located in the Town of Weston in Middlesex County, Massachusetts. The dam is located off Oak Street approximately 1,700 feet southwest of where Oak Street crosses the Massachusetts Turnpike. The dam impounds water from the MDC Hultman Aqueduct. Directly north of the dam is the MDC's Schencks Pond (see Report MA 00784). Norumbega Reservoir Dam is shown on the Natick, Massachusetts Quadrangle having the approximate coordinates of North $42^{\circ}20'05''$, West $71^{\circ}17'42''$.

b. Description of Dam and Appurtenances

Norumbega Reservoir is part of the MDC Hultman Aqueduct System. It is comprised of a 1,100 foot long, 25 foot high (hydraulic height) main earth embankment, plus 3 separate earth dikes and a 1,200 foot earth embankment access road (east dike). The main dam contains an ungated emergency spillway and a stone masonry gatehouse. See plan view in Appendix B for locations. The main dam embankment has a maximum structural height of $42\pm$ feet and a typical crest width of about 10 feet. The embankment contains an impervious central core, semi-impervious transition sections and consolidated pervious shells. The upstream slope is riprapped on a 2H:1V slope, photographs 1 and 2. The riprap is underlaid by a 12 inch crushed stone or by a screened gravel layer. The downstream slope is turf lined and sloped at 2H:1V, photographs 3 and 4. The embankment is founded on bedrock having a concrete cut-off. The rock below was grouted through shallow drill holes.

The 1,200 foot access service road embankment will be referred to as the east dike in this report. It has a common impact area with that of the main dam and therefore will have the same inventory number. The east dike is located to the right of the gatehouse. It contains an impervious core, a riprapped upstream slope and has a variable height of approximately 4 to 10 feet. The majority of this embankment would not retain water under normal pool elevation, of 269 or less. The top elevation of the east dike is 274.4.

The gatehouse is a stone masonry structure as shown by photograph 1. The MDC Hultman Aqueduct from Southborough traverses below the reservoir and gatehouse. There is also a gated 7-1/2 foot high by 6-1/2 foot wide concrete conduit which extends approximately 65 feet from an upstream intake structure into the gatehouse and a gated 5 foot high by 4 foot wide concrete conduit extending from the gatehouse to an outlet structure at Schencks Pond. Below the gatehouse, the Aqueduct has an opening which leads into a common well with the two conduits. The Aqueduct and the two conduits all contain provisions for stoplogs at their well entrance. Normally the gate leading to the Schencks Pond outlet is kept closed and the Aqueduct - Norumbega conduit well entrances are left open. By maintaining these controls in this configuration, an equal head between the Aqueduct and Norumbega Reservoir will automatically be established. See drawing B-10 in Appendix B. There is an overflow weir within the well chamber which is set at elevation 269.

When the elevation of the reservoir (or Aqueduct) exceeds this elevation, water will overflow the weir and enter the Schencks Pond outlet conduit through a 2 foot diameter cast iron pipe. See plans in Appendix B. There are also 4 inch ammonia and chlorine lines which feed the chemicals into the gatehouse from a chlorination storage house located approximately 200 feet downstream.

There is a 40+ foot long ungated emergency spillway located at the left abutment. The spillway is approximately 120 feet wide and is turf lined with placed mortared stone on the right side slope, see photographs 5, 6, 7 and 8 and plans in Appendix B.

There are three dikes located on the southern and western shores of the reservoir. The dikes all contain impervious cores and have riprapped upstream slopes at 2H:1V. The downstream slopes are turf lined and generally slope into existing topography on a 2H:1V slope. Dikes 2 and 4 have approximate lengths of 310 feet and 700 feet, respectively, and a maximum hydraulic height of 15 feet each. Dike 3 has a length of 500 feet, a maximum structural height of 15 feet and a riprapped upstream side slope inclined at 2H:1V similar to the other dikes. However, Dike 3 has a 40 foot wide lower berm upstream of its crest (service road). During construction spoil removed from the basin was apparently piled behind (downstream of) the crest. The magnitude of the spoil embankment above and behind the crest makes failure of this dike highly unlikely. If a failure were to occur, the impact area would be the same as that of Dike 2.

c. Size Classification

Norumbega Reservoir Dam and Dikes are being classified as small based on their maximum hydraulic height of 25 feet and storage capacity of 500 acre-feet.

d. Hazard Classification

The dam and dikes have high hazard classifications, due to the high potential for loss of life should dam or dikes fail. Based upon Corps Guidelines, the main dam and east dike, dike #2, and dike #4, have peak failure discharges of 37,380 cfs, 7,814 cfs and 7,814 cfs, respectively.

At the main dam, the spillway, prior to dam failure, will be discharging about 500 cfs. Flood stage throughout the impact area easterly along the Massachusetts Turnpike is about one to two feet deep. About 13 homes, the Massachusetts Turnpike and sideroads are flooded by this base flow.

Dam failure discharge flood stage varies from seven to 12 feet deep. The 13 homes impacted by base flow flooding receive additional flooding due to dam failure flooding conditions. There will also be another 20 homes impacted by dam failure flooding. Damage will be caused by two to five feet of flood water. The Massachusetts Turnpike and several sideroads are also flooded by dam failure flood waters.

Dikes #2 and #3 have a common impact area which extends westerly, along the Massachusetts Turnpike. There is no base flow flooding condition. One house is impacted near Wellesley Street. Flood and damage stage is about four feet deep. Another structure appears to be just above the flood stage and does not receive any apparent damage.

Dike #4 has an impact area which extends from Glen Road, Shady Hill Road and Woodchester Road, to Wellesley Street, south of that for dikes #2 and #3. There is no base flow flooding condition. Dam failure flood stage varies from three to ten feet deep. Flood damage to homes varies from two to six feet. At least 33 homes are damaged.

e. Ownership

The dam has always been owned by the MDC.

f. Operator

The dam is maintained and operated by the MDC. Mr. Charles Demeo is the designated caretaker. The address is Oak Street, Weston, Massachusetts 02193. (Telephone 617-235-2707).

g. Purpose of Dam

The dam is a part of the MDC high level water distribution system.

h. Design and Construction History

Design of the dam was completed in the late 1930's. Construction was completed in the early 1940's. There are no apparent post construction changes.

i. Normal Operational Procedures

The reservoir is part of the MDC water system from the Quabbin Reservoir. The Hultman Aqueduct traverses under the reservoir and gatehouse. The Aqueduct can automatically discharge water into and drain water from the reservoir, as demand varies. The reservoir is manned 24 hours per day. Every 2 hours the reservoir water level is determined and the

MDC station in Southborough is notified. Flow into the Hultman Aqueduct is regulated at Southborough. When the elevation of the Norumbega Reservoir exceeds 269, water flows over a gatehouse weir and into Schencks Pond below. If the level of downstream Schencks Pond is too low to maintain its outlet brook, water is discharged from the Norumbega Reservoir into Schencks Pond through the 7-1/2 x 6-1/2 and 5 x 4 foot conduits.

1.3 Pertinent Data

a. Drainage Area

The drainage area, 0.10 s.m. (63 acres) is undeveloped wooded land which is owned by the MDC. The reservoir has a surface area of about 50 acres at the top of dam. The surrounding land area, 13 acres, is just a "narrow" buffer of land around the reservoir. It provides very little runoff to replenish the reservoir.

The reservoir is a part of the MDC water supply system. The reservoir was formed by constructing about 3,800 feet of dam and dikes having a maximum height of 25 feet. There is one main dam with an attached service road which can act as a dike and 3 other dikes.

The Hultman Aqueduct passes beneath the northern part of the reservoir and below the dam at the gatehouse. Water from the aqueduct is discharged into the reservoir to maintain its level. The reservoir provides temporary storage for this water. Some water is discharged from Norumbega Reservoir into Schencks Pond and ultimately into Seaverns Brook.

Seaverns Brook flows 1.5 miles northeast into the Charles River, at Newton, Massachusetts. The brook crosses

Oak Street, 1,000 feet downstream of Schencks Pond. At Oak Street there is a small residential development. About 1,500 feet further downstream the brook flows under the Massachusetts Turnpike, towards another residential area and then to the Charles River.

b. Discharge at Damsite

1. Outlet Works

The outlet works consists of a reinforced concrete conduit measuring 7-1/2 feet wide by 6-1/2 feet high on the inlet side of the Aqueduct and 5 feet wide by 4 feet high on the outlet side. This 5 by 4 foot conduit outlets into Schencks Reservoir. The 7-1/2 by 6-1/2 foot inlet invert is at elevation 239± (NGVD). The 5 by 4 foot outlet invert elevation is 232±. The bottom of pond elevation 234.65± at the outlet conduit is slightly higher. With the 3 x 2 foot sluice gate open, the 5 x 4 foot outlet could discharge 100± cfs, depending upon available head.

The Hultman Aqueduct has an "automatic" overflow weir at elevation 269. This weir can discharge water into a 24 inch pipe which is connected to the 5 by 4 foot conduit. There are also provisions for stoplogs and screen on the Aqueduct, inside the gatehouse.

2. Maximum Known Flood

Records of maximum flooding conditions at the damsite were not available at the gatehouse. According to MDC personnel the dam has never been overtopped. Past records of daily reservoir readings are filed at the MDC Sudbury office. The U.S. Weather Bureau records indicate that between 10 to 12 inches of rainfall occurred near the project location between August 17 to 20, 1955.

3. Ungated Spillway Capacity at Top of Dam

The spillway has a maximum capacity of about 500 cfs. Its bottom elevation is 271.4₊. The top of dam elevation is 274.4. The spillway has no provisions for controls. The spillway outlets into Schencks Pond.

4. Ungated Spillway Capacity at Test Flood

At the test flood surcharge elevation of 272.8, the spillway discharge is 150 cfs.

c. Elevation (ft. above NGVD - approximate only)

- (1) Streambed at toe of dam ----- 234.65+
bottom of Schencks Pond
- (2) Bottom of cutoff ----- 234±
- (3) Maximum tailwater ----- 251.5+
overflows Schencks Dam
- (4) Water supply normal pool ----- 269.0±
- (5) Full flood control pool ----- N. A
- (6) Spillway crest ----- 271.4±
- (7) Design surcharge (Original Design) ----- Unknown
- (8) Top of dam ----- 274.4
- (9) Test flood surcharge ----- 272.8±

d. Reservoir (Length in feet)

- (1) Water supply normal pool ----- 1700±
- (2) Test flood pool ----- 1725±
- (3) Spillway crest pool ----- 1725±
- (4) Top of dam ----- 1750±
- (5) Flood control pool ----- N. A

e. Storage (acre-feet)

- (1) Water supply normal pool ----- 250
(elevation 269)
- (2) Spillway crest pool ----- 365
- (3) Test flood pool ----- 425
- (4) Top of dam ----- 500
- (5) Flood control pool ----- N. A

f. Reservoir Surface (acres)

- (1) Normal pool ----- 40
- (2) Spillway crest ----- 42.5

- (3) Test flood pool ----- 43.3
- (4) Top of dam ----- 50
- (5) Flood control pool ----- N/A

g. Dam

Dikes

	<u>Dike #2</u>	<u>Dike #3</u>	<u>Dike #4</u>	<u>East Dike</u>
(1) Type - earth, gravity		earth, gravity		
(2) Length - 1100 ft. main dam	310'±	500'±	700'±	1200'±
(3) Height - 25'± max.	15'	15'	15'±	10'±
(4) Top Width - 10'	10'	10'	10'	10'
(5) Side Slopes - u.s. & d.s.	2:1	u.s. and d.s. 2:1		
(6) Zoning - impervious, semi-impervious & pervious embankment		same as dam		
(7) Impervious Core - rolled impervious material		same as dam		
(8) Cutoff - concrete & impervious soil		same as dam		
(9) Grout curtain - bedrock grouted		same as dam		
(10) Other - crushed stone & riprap on U.S. toe drains		same as dam		

h. Diversion and Regulating Tunnel - none at this project

i. Spillway

- (1) Type ----- turf lined
- (2) Length of weir ----- 40'±
- (3) Crest elevation ----- 271.4±
(no flashboards)
- (4) Gates ----- None
- (5) U/S Channel ----- turfed
- (6) D/S Channel ----- heavily vegetated
- (7) General ----- right side slope lined with placed mortared stone

j. Regulating Outlets

The regulating outlets for the reservoir are an over-flow weir in the gatehouse at elevations 269, the stoplogs at the combined well chamber at elevation 232 and the 3 x 2 foot sluice gate for the 4 x 5 foot conduit at elevation 232. These can act as a main drain from Norumbega Reservoir into Schencks Pond. These culverts can be operated in combination so that Norumbega Reservoir can be drained.

SECTION 2
ENGINEERING DATA

2.1 Design Data

The dam was designed in the late 1930's. No indepth design calculations were located.

2.2 Construction Data

Construction of the dam was completed in 1940. As-built plans dated 1945 were made available by the MDC.

2.3 Operation Data

The dam is maintained and operated by the MDC. Flow in the Aqueduct is regulated by the upstream Southborough station based on periodic monitoring of the water level at Norumbega Reservoir. No formal operations manual for this project was made available.

2.4 Evaluation of Data

a. Availability

As-built plans were made available at the MDC Water Division Office at 20 Somerset Street, Boston, Massachusetts. A State Inspection Report dated 1974, was made available at the Department of Environmental Quality Engineering, Division of Waterways, Boston Office.

b. Adequacy

Indepth engineering data was not provided and does not allow for a definitive review. Therefore, the adequacy of this dam, structurally and hydraulically, cannot be assessed from the standpoint of review of design calculations, but must be based

primarily on the visual inspection, past performance history, the available as-built drawings, and sound engineering judgment.

c. Validity

The visual inspection of this facility showed no reason to question the validity of the information supplied.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General

At the time of inspection the water in the reservoir was about 6 feet below the top of the dam. Visual inspection of the main dam and east dike, dikes 2, 3 and 4 were made.

b. Dam

The main dam is zoned earth embankment about 1,100 feet in length and about 25 feet in height with an emergency spillway adjacent to the left abutment. The upstream slope of the main dam is protected by riprap which is in generally good condition, photographs 1 and 2. A small amount of brush and dead branches were observed on the upstream slope. An eroded area on the upstream slope to the right of the gatehouse is shown in photographs 9 and 10. This eroded area appears to have been caused by surface water runoff from the asphalt parking lot.

The crest of the dam is partly grass covered and partly covered with stone, photograph 11. Maintenance traffic has caused minor rutting of the surface. No evidence of cracking or misalignment of the crest that could be attributed to embankment movement was observed. The downstream slope of the main dam is shown in photographs 3 and 4. The slope is hummocky and contains many areas which are covered with brush growth. Several

bedrock or boulder outcrops up to 7 feet in the longest dimension were observed on the downstream slope and toe of the dam. An eroded areas was observed on the downstream slope near the gatehouse, photograph 12. A 6 inch I.D. clay pipe was observed in the above eroded area. A small channel was observed on the downstream slope near the gatehouse presumably caused by surface water runoff from the asphalt parking lot, photograph 13. No seepage was observed on the downstream side of the dam.

The east dike is zoned earth embankment about 1,200 feet long and about 10 feet in height with a roadway on the crest, photographs 14 and 15. Trees and brush were observed growing through the riprap on the upstream slope. The crest of the dike was covered with grass and gravel and showed no signs of cracking or misalignment that could be attributed to embankment movement. The downstream slope was covered with brush growth and showed no signs of seepage.

Dike 4 is a zoned earth embankment about 700 feet long and about 15 feet in height with a roadway on the crest. The upstream slope is covered with riprap in good condition, photograph 16. Large trees are growing on the upstream side of the right abutment. The crest of the dike, covered mainly with a gravel surfacing, showed no evidence of cracking or misalignment that could be attributed to embankment movement, photograph 17. The downstream slope and downstream area of this dike, photographs 17 and 18 are covered with grass and brush growth and showed no signs of seepage. At the time of inspection, the reservoir level was at about the same elevation as the downstream toe of the dike.

Dike 2 is zoned earth embankment about 310 feet long and about 15 feet in height and located over a pressure aqueduct designed to pass under the dike. The upstream slope is covered with riprap in good condition with the exception of tree growth near the top, photographs 19 and 20. The crest of the dike, shown in photograph 19, is used as a roadway and is covered with grass and a gravel surfacing. No evidence of cracking or misalignment of the crest that could be attributed to embankment movement was observed. The downstream slope is covered with grass, brush growth, and small trees, photograph 21. A drainage ditch was observed on the downstream left side of the dike. Water was observed in the ditch starting at the location of a 6 inch diameter clay pipe oriented roughly perpendicular to the crest of the dike, photographs 22 and 23. It is not known if the clay pipe is an outlet for a toe drain in the dike. The right abutment of the dike is a bedrock ridge.

Dike 3 has a length of 500 feet and a maximum structural height of 15 feet as shown by photograph 27. It has a riprap upstream slope inclined at 2H:1V. Dike 3 contains a 40± foot berm upstream of the crest. During construction, spoil material removed from the reservoir area was apparently piled behind the crest. The magnitude of the spoil material above and behind the crests makes failure of this dike highly unlikely.

2. Appurtenant Structures

The spillway is located next to the left abutment of the main dam. The floor of the spillway is grass covered, photograph 5. The right side of the spillway channel is covered with mortared stone, as shown in photograph 6 and the spillway crest

consists of an 18 inch wide concrete wall, as shown in photograph 7. A bedrock or boulder outcrop was observed at the spillway entrance. The downstream area of the spillway is heavily forested, as shown in photograph 8.

The intakes to the gatehouse were underwater and could not be inspected. Separation of asphalt paving from the downstream wall of the masonry gatehouse was observed, as shown in photograph 24. Pipes were observed entering the asphalt paving at the right and left sides of the downstream wall of the gatehouse photographs 24 and 25. The stone masonry gatehouse structure, photograph 1, was in generally good condition. All gate valves and stoplogs are reported to be operable.

d. Reservoir Area

Bedrock outcrops were observed in the reservoir. There are no indications of instability along the banks of the reservoir in the vicinity of the dam or dikes.

e. Downstream Channel

Water which flows over the spillway enters Schencks Pond.

3.2 Evaluation

Visual inspection indicates the dam and dikes are in generally good condition. However, due to excessive growth of brush and trees on the slopes of the dam and dikes and the lack of seismic stability investigation, the overall rating is fair.

No evidence of seepage through the dam or dikes was observed; however, the reservoir was not at its highest level. Minor erosion on the upstream and downstream slopes of the dam and brush and tree growth on the dam and dikes do not represent an immediate stability problem but should be corrected as recommended in Section 7.

SECTION 4

OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 Operational Procedures

a. General

Norumbega Reservoir Dam is a high level distribution facility on the MDC Hultman Aqueduct. The Aqueduct can automatically discharge water into and drain water from the reservoir as demand varies. The reservoir is monitored 24 hours per day. Water levels are periodically taken and the discharge from upstream Southborough MDC station regulated accordingly. When the water level of Schencks Pond located immediately downstream is too low to maintain flow in its outlet brook or the level of Norumbega exceeds elevation 269, water is discharged into Schencks.

b. Description of Warning System

There is no warning system to notify the impact area in the event of an emergency. However, the gatehouse is monitored 24 hours per day.

4.2 Maintenance Procedures

a. General

The MDC is responsible for the maintenance of the facility. There is no formal maintenance schedule. MDC personnel perform periodic maintenance as required.

b. Operating Facilities

The gatehouse is manned by MDC personnel 24 hours per day. The facilities related to the Aqueduct can be assessed

(and repaired when necessary) based on daily operation. The gate controls for the Norumbega outlet into Schencks, is used infrequently, but is reportedly operable.

4.3 Evaluation

There are no formal maintenance procedures for the dam. MDC personnel perform maintenance as required. Brush growth and trees on the upstream and downstream slopes should be cut as part of routine maintenance. The dam should be inspected every year by a qualified registered professional engineer who can identify areas of concern, which if left unchecked could jeopardize the safety of the dam.

SECTION 5

EVALUATION OF HYDRAULIC/HYDROLOGIC FEATURES

5.1 General

Norumbega Reservoir is located in the Town of Weston, Massachusetts about 1,000 feet south of the Massachusetts Turnpike. The reservoir is part of the MDC water supply system. The Hultman Aqueduct supplies water to the reservoir. It is a temporary storage facility.

The reservoir was formed by constructing about 3,800 feet of dam and dikes at the location of an existing pond (Schencks Pond). The maximum height of these embankments range between 15 and 25 feet. The natural, reservoir drainage area is about 63 acres in size. The 13 acre land area around the 50 acre reservoir is a very narrow buffer. The reservoir receives little runoff from the small 13 acre drainage area.

See Appendixes B, C and D for engineering data, photographs and hydraulic/hydrologic information.

5.2 Design Data

The reservoir was designed in the late 1930's and built in the early 1940's. Original design data was not located for inclusion in this report. Original construction plans were obtained from the MDC.

5.3 Experience Data

There are no records kept at the gatehouse, of the dam ever being overtopped or of past flood experience. According to MDC personnel the dam has never been overtopped. Past records of daily reservoir readings are kept at the MDC Sudbury office. The small size of the reservoir's drainage area would limit the amount of runoff even from the largest storms.

The U.S. Weather Bureau records indicate that from August 17 to 20, 1955 about 10 to 12 inches of rainfall occurred near the project location.

5.4 Test Flood Analysis

Norumbega Reservoir has a small size classification and high hazard potential. Based upon Corps Guidelines the test flood would be in the 1/2 PMF to PMF range. The PMF was chosen due to the amount of development within the dam failure impact area. The test flood inflow from the 0.10 s.m. drainage area is 300 cfs.

Assuming the initial water surface was at the spillway level, elevation 271.4, the test flood would surcharge the reservoir to elevation 272.8. This level is 1.6± feet below the top of dam, elevation 274.4. The test flood outflow through the spillway is 150 cfs. Normally, the water surface elevation is kept at 269±, or less. This would provide enough storage capacity to retain the entire 108 acre-feet PMF runoff.

5.5 Dam Failure Analysis

Dam failure analysis was performed assuming the initial water level at elevation 274.4±, top of dam. The main dam and the four dikes have three separate dam failure impact areas. Failure analysis was performed for the three impact areas of the main dam (and east dike) and dikes #2 (and #3) and #4, as shown on the dam failure impact map in Appendix D. Since dike #3 has the same hydraulic height and impact area as dike #2, it was not analyzed for dam failure. Similarly, the east dike has the same impact area as the main dam and it was not analyzed separately. It was assumed that the Hultman Aqueduct water flow into Norumbega

Reservoir would be stopped by MDC personnel. This would be accomplished by installing stoplogs into the concrete bulk-head between the Hultman Aqueduct and the Norumbega intake channel. See gate-house plan in Appendix B.

Main Dam

Considering a failure at the main dam, the peak failure discharge from a 25 foot high, 445 foot long section, is 37,389 cfs. The spillway would be discharging 500 cfs just prior to failure. Flood damage caused by the 500 cfs base flow was determined so that the damage caused by each condition could be assessed. These flows were then combined and routed downstream using the Crops Rule of Thumb method to determine the dam failure impact area. Failure stage includes base flow stage.

The access road dike is a continuation of the main dam. A failure of this dike would impact the same general area as the main dam. But, this failure discharge, flood stage depths, and resulting damage would be significantly less than the main dam.

The initial dam failure discharge will overflow Schencks Pond dam, located approximately 1,000 feet downstream, by about seven feet. Schencks Pond Dam was not assumed to have failed. The flood wave will continue toward Oak Street, about 700 feet further downstream.

The first impact area occurs between 1,600 to 1,800 feet downstream. Base flow flood stage is about one foot deep in this area. About six homes and Oak Street receive about one foot of flood damage from base flow. Dam failure flood stage is about seven feet deep. The six homes damaged by base flow flooding are also damaged by dam failure flooding. Eight other homes receive dam failure flood damage of about two feet.

At station 24+00, base flow flooding is two feet deep. Two homes are damaged by about two feet of water. Dam failure flood stage is about 12 feet. The same two homes receive an additional ten feet of flooding damage.

Near station 35+00, the Massachusetts Turnpike is flooded by a base flow stage about two feet deep. The dam failure flood stage is about nine feet deep.

The fourth impact area occurs near station 42+00. Here, three homes are damaged by base flow flood water about two feet deep. Dam failure flood stage is about seven feet deep. The three homes damaged by base flow flooding are also damaged by dam failure flooding. Three other homes receive five feet of flood damage due to dam failure.

The fifth impact area occurs near station 53+00. Base flow flooding about one foot deep impacts two homes. Dam failure flood stage is about eight feet deep. South Avenue is flooded by at least two feet of water. The two homes flooded by the base flow receive dam failure flooding. Nine additional homes are damaged by about two feet of dam failure flood water.

Beyond this area, additional flooding could occur at the Massachusetts Turnpike and Route 128 interchange as the remaining dam failure outflow of 24,300+ cfs flows into the Charles River.

Dike #2

The second failure analysis was done for Dike #2. The impact area is along the Aqueduct right-of-way towards Wellesley Street and the swamp area near the Massachusetts Turnpike. At this

location with water assumed at the crest of the dike, a 200 foot long dike section, 15 feet high, fails and develops a peak discharge of 7,800± cfs. This dike does not contain a spillway thus, there will be no base flow flooding condition. Dike #3 was not analyzed for failure but it has the same impact area as dike #2.

The area downstream is undeveloped until Wellesley Street at station 27+00. Here, there are two residential structures. Their approximate ground elevations are 210 and 200. Two barns are at elevation 200. The house at elevation 210± appears to be above the flood level of 205±. The remaining house and two barns could receive up to five feet of flood damage due to dam failure.

Beyond this location, the remaining outflow of 6,730 cfs could continue further downstream and cause additional flood damage near Winter Street.

Dike #4

The third failure analysis was performed for dike #4, near Glenn Road. Dike #4 does not contain a spillway, therefore there is no base flow flooding condition. The failure discharge of 7,814± cfs was developed by considering a 200 foot long section of the 15 foot high embankment failed with water to the crest. The failure discharge will flow westerly, towards the swampy area beyond Wellesley Street, about 4,000 feet downstream.

Within the first 1,000 foot downstream impact area, the dam failure flood stage varies from six to ten feet. Glen Road is flooded by six feet of water. Three homes are also damaged. Two by five feet and one by two feet of flood water.

Between stations 10+00 and 32+00 downstream, dam failure flood stage is six feet deep. Thirteen homes receive at least two feet of flood damage. About 15 homes receive about six feet of flood damage. Part of Wellesley Street is also flooded by about four feet of flood water.

Between station 32+00 and Wellesley Street at station 38+00, flood stage varies from six to three feet. Ten homes receive about four feet of flood damage. Two houses and Wellesley Street receive about three feet of flood damage.

Beyond this location, the remaining 6,534 cfs discharge could cause additional damage near the Winter Street and Nonesuch Pond area.

The main dam and dikes 2 (and 3) and 4 are all high hazard. The possibility of loss of life occurring from the failure of the dam or dikes is high.

SECTION 6
EVALUATION OF STRUCTURAL STABILITY

6.1 Visual Observations

The visual observations did not disclose any immediate stability problems. However, several problems were observed which, if allowed to continue, could lead to instability of the dam or dikes in the future. These are:

- a. erosion of the upstream and downstream slopes of the main dam near the gatehouse.
- b. tree growth on the upstream and downstream slopes of the dikes.

6.2 Design and Construction Data

Design drawings by the Commonwealth of Massachusetts Metropolitan District Water Supply Commission dated 1944 were reviewed. The dam and dikes were constructed around 1940.

The following geotechnical information was obtained from a drawing of typical cross sections through the dam and dikes:

- a. The upstream and downstream slopes of the dam and dikes are 2H:1V.
- b. The dam and dikes are zoned earth embankments with cores consisting of "rolled impervious" soil.
- c. The dam and dikes are founded on earth with the exception of the cores which are founded on bed-rock. A separate drawing showing a cross section of the east dike from Sta. 12+00 to Sta. 15+00 indicates that the core in this distance may rest on a soil foundation.

- d. The rock beneath the core was grouted through shallow drill holes. A concrete slab was placed on a cleaned rock surface. An exception to the above is for the east dike between Sta. 12+00 and Sta. 15+60 where no grouting was performed and no concrete cutoff was placed.

Design drawings indicate that borings and test pits were made at the location of and in the vicinity of the dam and dikes. Logs of some of the test pits are given in the design drawings, but no boring logs are given. Bedrock outcrops are indicated on several of the design drawings.

Design drawings of the spillway indicate that it has a bedrock floor.

Photobooks of the dam and dike construction exist but were not critically reviewed for the Phase I level of investigation.

6.3 Post Construction Changes

No significant post construction changes to the dam are known.

6.4 Seismic Stability

The dam is located near the boundary of Seismic Zones 2 and 3. Considering its height, a seismic stability investigation should be conducted as recommended in Section 7.

SECTION 7

ASSESSMENT, RECOMMENDATIONS & REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition

On the basis of the visual inspection and available records, the dam and dikes are judged to be in generally good condition. However, due to excessive growth of brush and trees on the slopes of the dam and dikes and the lack of seismic stability investigations, the overall rating is fair.

b. Adequacy of Information

The information made available and the visual inspection are adequate for a Phase I level of inspection.

c. Urgency

The recommendations and remedial measures presented in Sections 7.2 and 7.3 should be implemented within one year after receipt of this Phase I Inspection Report by the Owner.

7.2 Recommendations

The Owner should engage a qualified registered professional engineer to investigate and design required remedial measures for:

a. Means of removing trees and roots from the dam and dikes and selecting acceptable backfill for holes caused by root removal.

b. The seismic stability of the dam in accordance with Phase I guidelines.

7.3 Remedial Measures

a. Operation and Maintenance Procedure

1. Surface water runoff from asphalt parking lot near the gatehouse should be prevented from flowing down the upstream slopes of the dam. Eroded areas on the upstream and downstream slopes caused by past runoff should be repaired.

2. Brush growth and trees on the upstream and downstream slopes of the dam and dikes and the spillway floor should be cut as a part of the MDC's routine annual maintenance. Grass cover should be established and cut several times each growth season as a part of routine annual maintenance.

3. The Owner should establish a formal warning system for notifying downstream areas in the event of an emergency.

4. The Owner should prepare a formal emergency operational procedure for its personnel to be kept at the gatehouse. This should include a procedure for monitoring the reservoir water surface level during periods of heavy rainfall and the determination of when stoplogs should be installed to stop the flow of water from the Hultman Aqueduct into Norumbega Reservoir and Schencks Pond.

5. The dam and dikes should be inspected every year by qualified registered professional engineers who can identify conditions of concern which if left unchecked could jeopardize the safety of the dam. This inspection should be performed at both high and low reservoir levels.

7.4 Alternatives

There are no practical alternatives for the recommendations.

APPENDIX A
INSPECTION CHECKLIST

A-1

Norumbega Reservoir Dam & Dikes

WATER RESOURCES DIVISION U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

PROJECT NORUMBEGA RESERVOIR DAM & DIKESDATE Oct. 30, 1979TIME 8 amWEATHER 64° F, SunnyWIND 269+ 11.3 11.3

PARTICIPANTS

1. <u>R. Cheney, HHB</u>	6. <u></u>
2. <u>D. Vine, HHB</u>	7. <u></u>
3. <u>D. LaGatta, GEI</u>	8. <u></u>
4. <u>T. Keller, GEI</u>	9. <u></u>
5. <u></u>	10. <u></u>

PROJECT COMPONENT	DESIGNED BY	APPROVED BY
<u>Embankment Dam</u>	<u>D. LaGatta,</u>	<u>T. Keller</u>
<u>Dikes</u>	<u>D. LaGatta</u>	<u>T. Keller</u>
<u>Spillway</u>	<u>All</u>	
<u>Gatehouse</u>	<u>All</u>	
<u></u>		
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NORUMBEGA RESERVOIR DAM & DIKES		Oct. 30, 1979																																												
PROJECT TYPE	Embankment Dam	NAME D. LaGatta																																												
DISCIPLINE	Geotechnical Engineer	NAME R. Cheney																																												
Structual Engineer																																														
<table border="1"> <thead> <tr> <th>Inspection Item</th> <th>Condition</th> </tr> </thead> <tbody> <tr> <td>Crest Elevation</td> <td>274.4 (NGVD-Approx)</td> </tr> <tr> <td>Current Pool Elevation</td> <td>269+</td> </tr> <tr> <td>Maximum Impoundment to Date</td> <td>Unknown</td> </tr> <tr> <td>Surface Cracks</td> <td>None of significance.</td> </tr> <tr> <td>Pavement Condition</td> <td>Pavement separated from downstream wall of outlet structure.</td> </tr> <tr> <td>Movement or Settlement of Crest</td> <td>None observed.</td> </tr> <tr> <td>Internal Movement</td> <td>None observed.</td> </tr> <tr> <td>Vertical Alignment</td> <td>No vertical misalignment observed.</td> </tr> <tr> <td>Horizontal Alignment</td> <td>No horizontal misalignment observed.</td> </tr> <tr> <td>Condition at Abutment and at Concrete Structures</td> <td>Good.</td> </tr> <tr> <td>Indications of Movement of Structural Members or Slopes</td> <td>None.</td> </tr> <tr> <td>Transgression on Slopes</td> <td>None observed.</td> </tr> <tr> <td>Sloughing or Erosion of Slopes or Abutments</td> <td>Erosion channels on downstream and upstream slopes caused by runoff from parking lot; downstream slope is hummocky.</td> </tr> <tr> <td>Rock Slope Protection - Riprap Failures</td> <td>None observed.</td> </tr> <tr> <td>Internal Movement or Settlement or Near Toe</td> <td>None observed.</td> </tr> <tr> <td>Downstream Elevation or Downstream Embankment</td> <td>None observed.</td> </tr> <tr> <td>Presence of Weirs</td> <td>None observed.</td> </tr> <tr> <td>Foundation Drainage Features</td> <td>None observed.</td> </tr> <tr> <td>Tree Growth</td> <td>None observed.</td> </tr> <tr> <td>Interior Retention System</td> <td>None.</td> </tr> <tr> <td>Vegetation</td> <td>Brush on downstream slope.</td> </tr> </tbody> </table>			Inspection Item	Condition	Crest Elevation	274.4 (NGVD-Approx)	Current Pool Elevation	269+	Maximum Impoundment to Date	Unknown	Surface Cracks	None of significance.	Pavement Condition	Pavement separated from downstream wall of outlet structure.	Movement or Settlement of Crest	None observed.	Internal Movement	None observed.	Vertical Alignment	No vertical misalignment observed.	Horizontal Alignment	No horizontal misalignment observed.	Condition at Abutment and at Concrete Structures	Good.	Indications of Movement of Structural Members or Slopes	None.	Transgression on Slopes	None observed.	Sloughing or Erosion of Slopes or Abutments	Erosion channels on downstream and upstream slopes caused by runoff from parking lot; downstream slope is hummocky.	Rock Slope Protection - Riprap Failures	None observed.	Internal Movement or Settlement or Near Toe	None observed.	Downstream Elevation or Downstream Embankment	None observed.	Presence of Weirs	None observed.	Foundation Drainage Features	None observed.	Tree Growth	None observed.	Interior Retention System	None.	Vegetation	Brush on downstream slope.
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PERIODIC INSPECTION CHECKLIST

PROJECT NORUMBEGA RESERVOIR DAM & DIKES DATE October 30, 1979
 PROJECT FEATURE East Dike and Dike #2 NAME D. LaGatta
 DISCIPLINE Geotechnical Engineer NAME R. Cheney
Structural Engineer

AREA EVALUATED	CONDITION	
<u>DAM EMBANKMENT</u>	<u>East Dike</u>	<u>Dike #2</u>
Crest Elevation	274.4	274.4
Current Pool Elevation	269±	269±
Maximum Impoundment to Date	Unknown	Unknown
Surface Cracks	None of signifi- cance.	None of signifi- cance.
Pavement Condition	None.	None.
Movement or Settlement of Crest	None observed.	None observed.
Lateral Movement	None.	None.
Vertical Alignment	Good.	Good.
Horizontal Alignment	Good.	Good.
Condition at Abutment and at Concrete Structures	Good.	Good - right abutment is rock.
Indications of Movement of Structural Items on Slopes	None.	None.
Trespassing on Slopes	None observed.	None observed.
Sloughing or Erosion of Slopes or Abutments	None observed.	None observed.
Rock Slope Protection - Riprap Failures	None observed.	None observed.
Unusual Movement or Cracking at or Near Toe	None observed.	None observed.
Unusual Embankment or Downstream Seepage	None.	None.
Piping or Boils	None.	None.
Foundation Drainage Features	None observed.	Possible toe drain, 6" clay pipe.
Toe Drains		
Instrumentation System	None.	None.
Vegetation	Brush and trees on slopes.	Brush and trees on slopes.

PERIODIC INSPECTION CHECKLIST

PROJECT NORUMBEGA RESERVOIR DAM & DIKES DATE October 30, 1979
 PROJECT FEATURE Dike #3 and Dike #4 NAME D. LaGatta
 DISCIPLINE Geotechnical Engineer NAME R. Cheney
Structural Engineer

AREA EVALUATED	CONDITION	
<u>DAM EMBANKMENT</u>	<u>Dike #3</u>	<u>Dike #4</u>
Crest Elevation	274.4	274.4
Current Pool Elevation	269+	269+
Maximum Impoundment to Date	Unknown	Unknown
Surface Cracks	None of signifi- cance.	None of signifi- cance.
Pavement Condition	None.	None.
Movement or Settlement of Crest	None observed.	None observed.
Lateral Movement	None.	None.
Vertical Alignment	Good.	Good.
Horizontal Alignment	Good.	Good.
Condition at Abutment and at Concrete Structures	Good.	Good.
Indications of Movement of Structural Items on Slopes	None.	None.
Trespassing on Slopes	None observed.	None observed.
Sloughing or Erosion of Slopes or Abutments	None observed.	None observed.
Rock Slope Protection - Riprap Failures	None observed.	None observed.
Unusual Movement or Cracking at or Near Toe	None observed.	None observed.
Unusual Embankment or Downstream Seepage	None.	None.
Piping or Boils	None.	None.
Foundation Drainage Features	None observed.	None observed.
Toe Drains		
Instrumentation System	None.	None.
Vegetation	Brush and trees on slopes.	Brush and trees on slopes.

CONTRACT NO. 100-1-100-1-100-1

PROJECT NORUMBEGA RESERVOIR DAM & DIKES DATE October 30, 1979
 PROJECT HEADLINE Intake Structure NAME D. LaGatta
 DISCIPLINE Geotechnical Engineer NAME R. Cheney
 Structural Engineer

AREA EVALUATED	REMARKS
<p>PROJECT NO. 100-1-100-1-100-1</p> <p>PROJECT HEADLINE <u>Intake Structure</u></p> <p>a. Approach Channel</p> <p> Bench Conditions</p> <p> Bottom Conditions</p> <p> Rock Slopes or Falls</p> <p> Lift Low</p> <p> Lift High</p> <p> Condition of Concrete Structure</p> <p> Condition of Masonry Structure</p> <p>b. Intake Structure</p> <p> Condition of Concrete Structure</p> <p> Condition of Masonry Structure</p>	<p>Intake channel is the reservoir.</p> <p>Stone masonry gatehouse was in good condition.</p>

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PROJECT <u>NORUMBEGA RESERVOIR DAM & DIKES</u>		DATE <u>Oct. 30, 1979</u>
PROJECT TEAM <u>Control Tower</u>		NAME <u>D. LaSatta</u>
DISCIPLINE <u>Geotechnical Engineer</u>		NAME <u>R. Cheney</u>
Structural Engineer		
AREA EVALUATED		REMARKS
<u>INLET WORKS - DAMING TOWER</u>		
a. Concrete and Structural		There is no control tower.
General Condition		
Condition of Joints		
Cracking		
Visible Reinforcement		
Rusting or Spalling of Concrete		
Dry Seepage or Efflorescence		
Joint Alignment		
General Condition of Locks in Gate Chamber		
Tracks		
Rusting or Corrosion of Steel		
Mechanical and Electrical		
Air Vents		
Float Weirs		
Crane Mount		
Elevator		
Hydraulic System		
Service Gates		
Emergency Gates		
Inlet Protection System		
Emergency Drain System		
Other		

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<p align="center">NORUMBEGA RESERVOIR DAM & DIKES</p>	
DATE	Oct. 30, 1970
PROJECT FEATURES	Outlet Works
NAME	D. LaGatta
DISCIPLINE	Geotechnical Engineer
NAME	R. Cheney
Structural Engineer	
DESCRIPTION	LOCATION
<p><u>OUTLET WORKS - TRANSITION AND CONDUIT</u></p> <p>General Condition of Concrete</p> <p>Cost or Spalling on Concrete</p> <p>spalling</p> <p>Incision or Cavitation</p> <p>Cracking</p> <p>Alignment of Monoliths</p> <p>Alignment of Joints</p> <p>Weathering of Monoliths</p>	<p>The MDC Hultman Aqueduct travels below the dam. It could not be inspected.</p>
<p>Copy available to DTIC does not permit fully legible reproduction</p>	

REPORT TO INSPECTION CHECKLIST

PROJECT NORUMBEGA RESERVOIR DAM & DIKES DATE Oct. 30, 1979

PROJECT FEATURE Spillway NAME D. LaGatta

DISCIPLINE Geotechnical Engineer NAME R. Cheney

Structural Engineer

AREA EVALUATED	CONDITION
<u>EXIST WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNEL</u>	
a. Approach Channel	
General Condition	Fair - no erosion protection for floor.
Loose Rock Overhanging Channel	None.
Trees Overhanging Channel	Trees on left side of channel.
Floor of Approach Channel	Grass covered.
b. Weir and Training Walls	
General Condition of Concrete	No training wall;
Rust or Staining	Concrete weir is in good condition.
Cracking	
Any Visible Reinforcing	
Any Spalling or Efflorescence	
Drain Holes	None.
c. Discharge Channel	
General Condition	Fair - no erosion protection for floor.
Loose Rock Overhanging Channel	None.
Trees Overhanging Channel	Trees in channel.
Floor of Channel	Grass covered.
Other Obstructions	None.

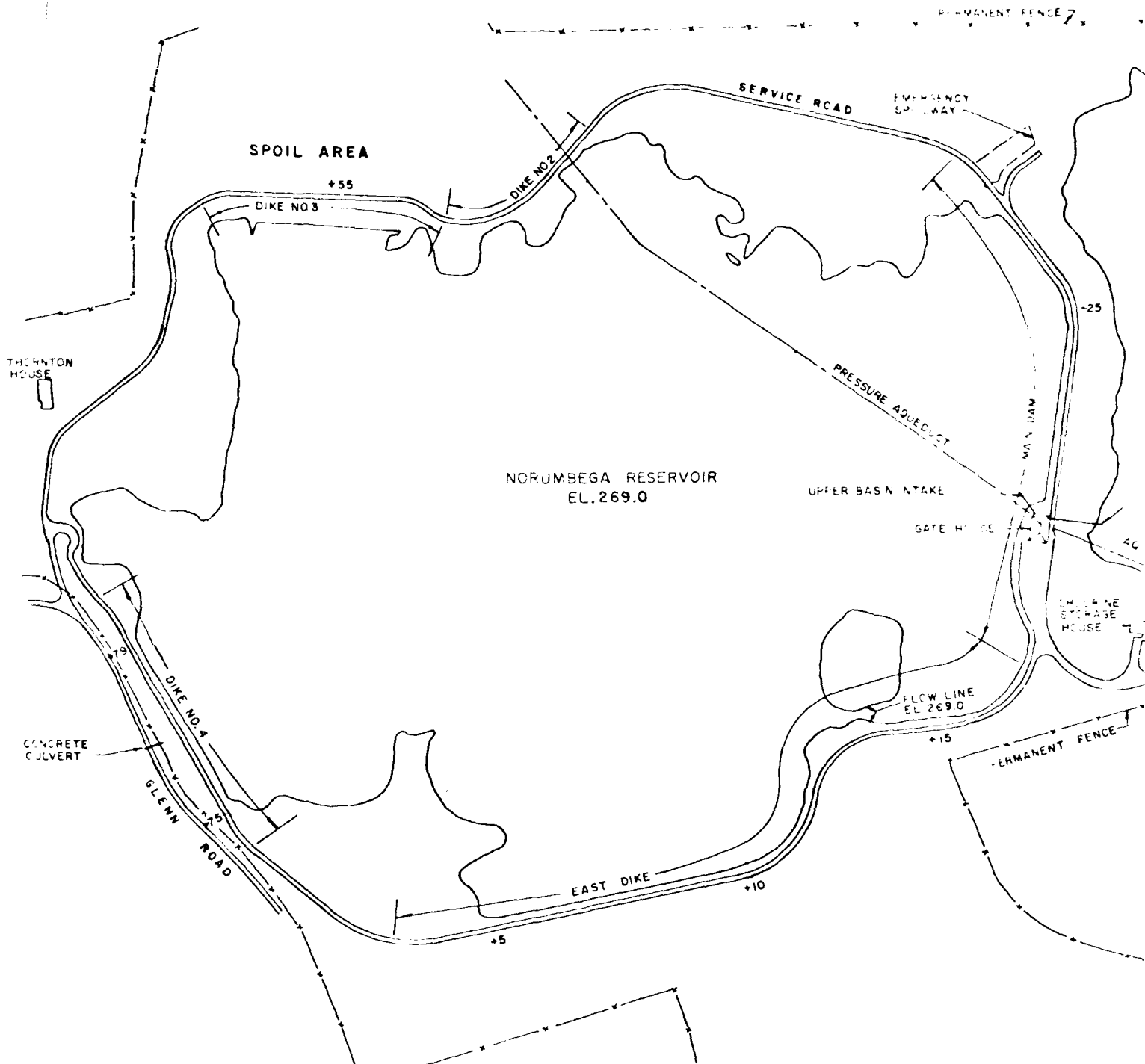
Copy available to DTIC does not permit fully legible reproduction

FEDERAL BUREAU OF INVESTIGATION			
PROJECT	NOBUMBEGA RESERVOIR DAM & DIKES	DATE	Oct. 30, 1979
PROJECT NAME	Service Bridge	NAME	D. LaGatta
SUBJECT LINE	Geotechnical Engineer	NAME	R. Cheney
Structural Engineer			
<p>1. General Information</p> <p>2. Project Description</p> <p>3. Bridge Structure</p> <p>4. Foundation</p> <p>5. Abutments</p> <p>6. Piers</p> <p>7. Deck</p> <p>8. Approach</p> <p>9. Drainage</p> <p>10. Utilities</p> <p>11. Construction</p> <p>12. Maintenance</p> <p>13. Inspection</p> <p>14. Rehabilitation</p> <p>15. Demolition</p>		<p>There is no service bridge.</p>	

APPENDIX B
ENGINEERING DATA

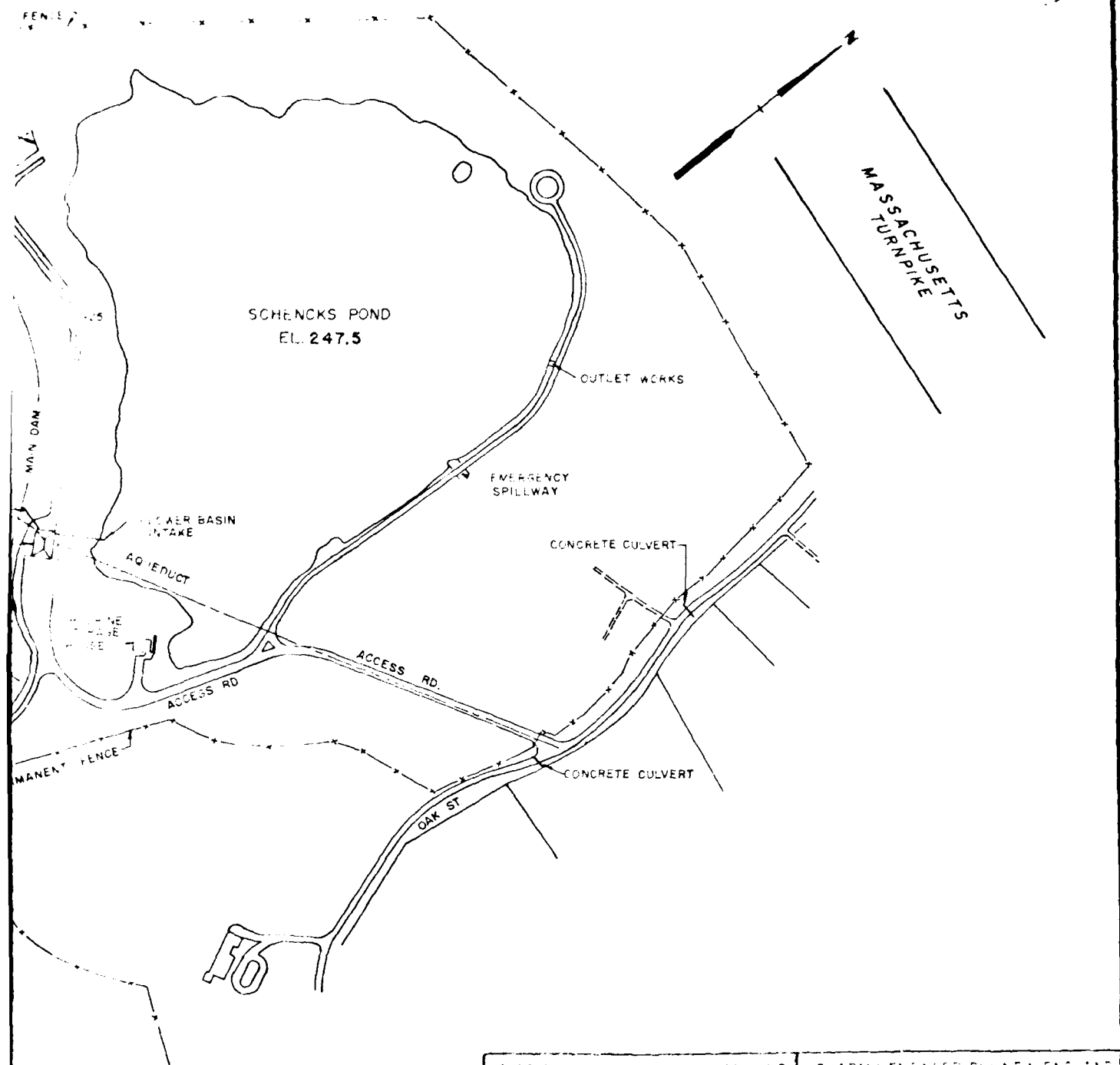
LIST OF ENGINEERING DATA

1. As-built plans dated 1944 were available at the MDC Water Division Office at 20 Somerset Street, Boston, Massachusetts.
2. A State Inspection Report dated 1974 was available at the Department of Environmental Quality Engineering, Division of Waterways, 100 Nashua Street, Boston, Massachusetts.



NOTE:

TAKEN FROM METR. DIST. WATER SUPPLY COMM. DWG. DATED MAY
ELEVATION SHOWN ARE NGVD



HAYDEN, HARDING & BLOCHMAN, INC.
CONSULTING ENGINEERS
BOSTON, MASSACHUSETTS

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS

NORUMBEGA RESERVOIR DAM PLAN

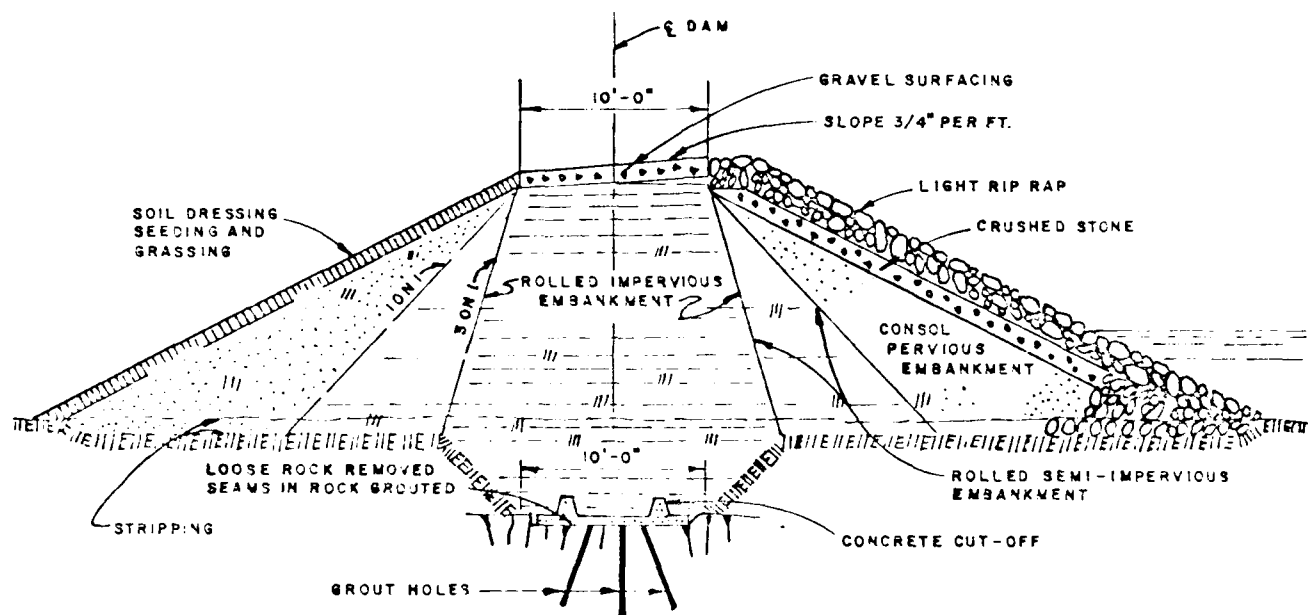
WESTON

MASSACHUSETTS

SCALE: NOT TO SCALE

DATE: FEBRUARY 1980

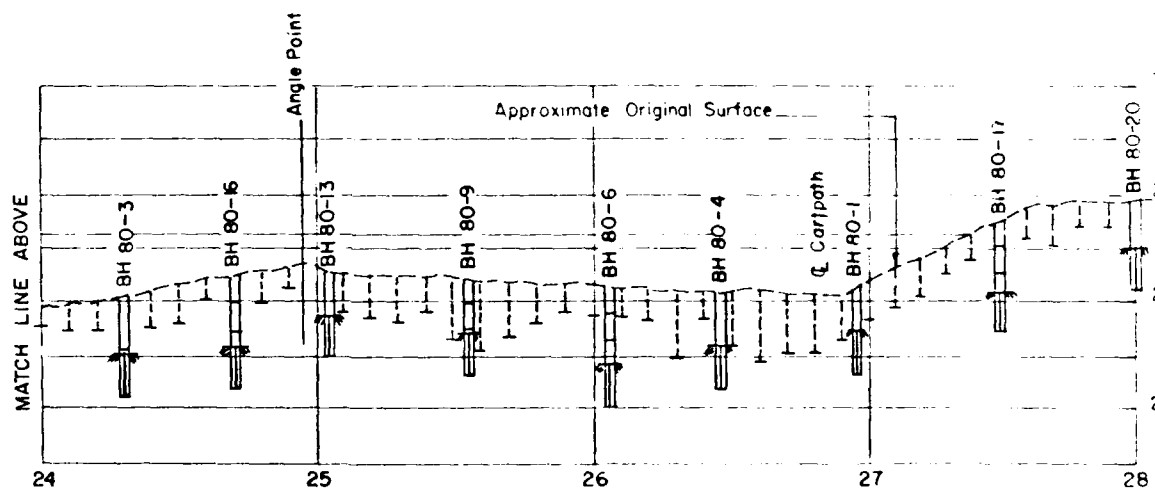
WG DATED MAY 13, 1941



NOTE

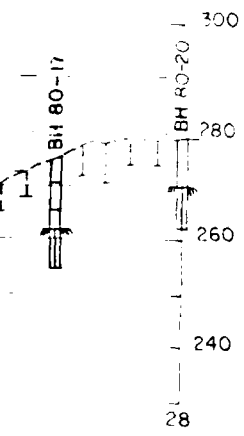
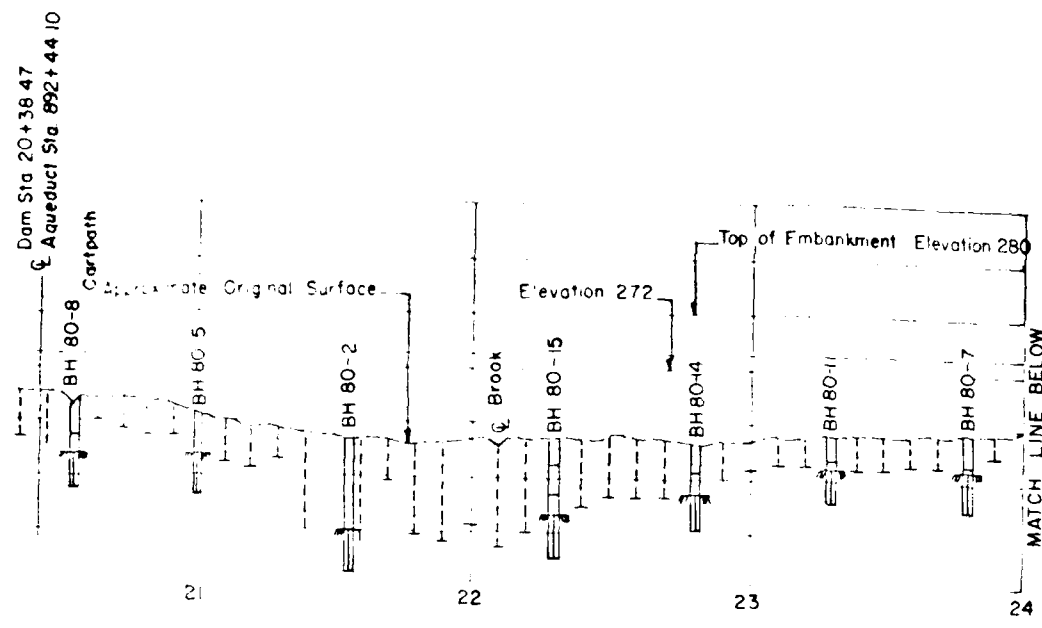
TAKEN FROM METR. DISTR. WATER SUPPLY COMM. DWG. DATED FEB. 1, 1944
ELEVATION SHOWN ARE BOSTON CITY BASE

HAYDEN, HARDING & BUCHANAN, INC CONSULTING ENGINEERS BOSTON, MASSACHUSETTS			U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.		
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS					
NORUMBEGA RESERVOIR DAM TYPICAL CROSS SECTION					
WESTON			MASSACHUSETTS		
			SCALE NOT TO SCALE		
			DATE FEBRUARY 1980		



NOTE:

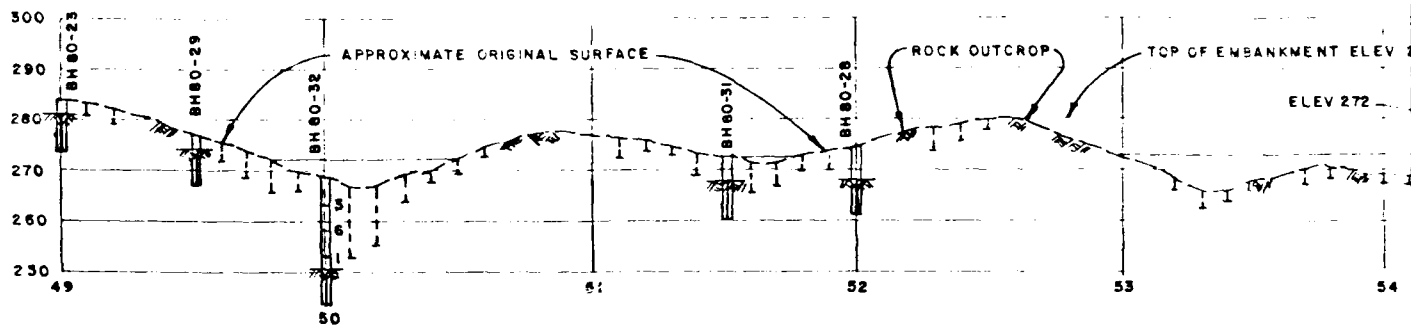
B - 5



R-LINE MAIN DAM AND EAST DIKE

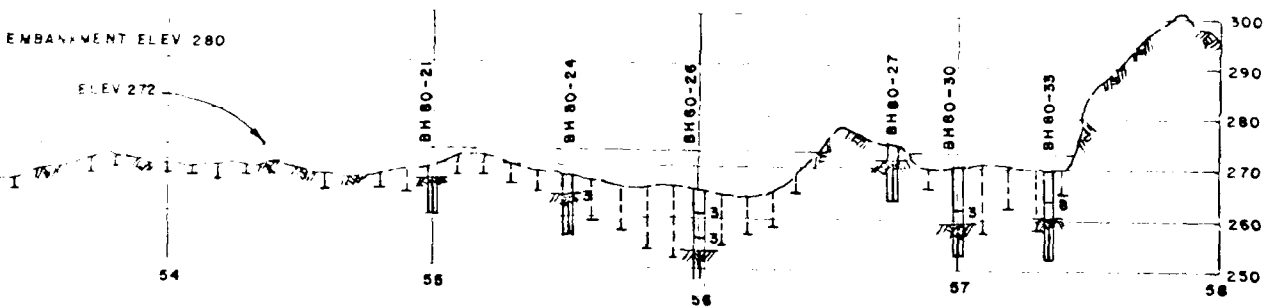
IN DRAWING DATED APRIL 29, 1939.

HAYDEN, HARDING & RICHMAN, INC. CONSULTING ENGINEERS BOSTON, MASSACHUSETTS		U.S. ARMY ENGINEER IN NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS	
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS			
NORUMBEGA RESERVOIR DAM MAIN DAM AND EAST DIKE PROFILE			
WESTON		MASSACHUSETTS	
		SCALE NOT TO SCALE	
		DATE FEBRUARY, 1980	



PROFILE ON CENTER LINE DIKES

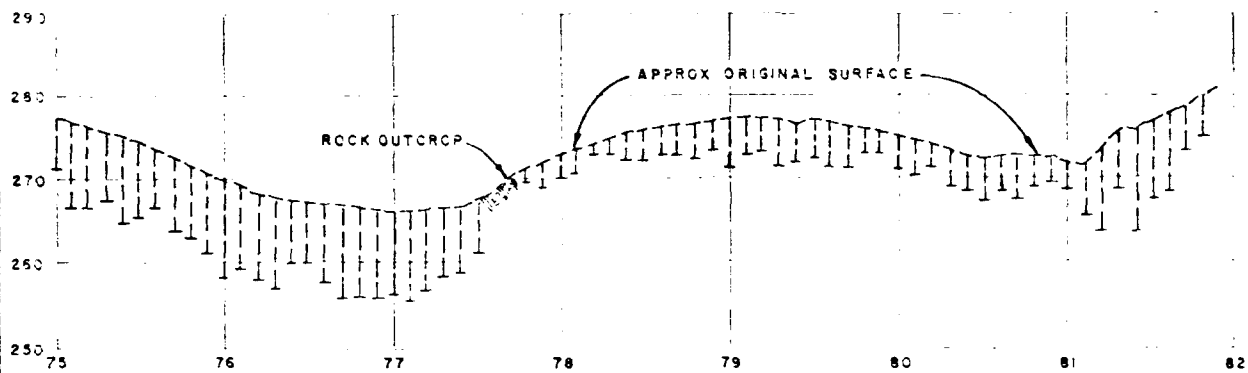
NOTE:
TAKEN FROM METR. DISTR. WATER SUPPLY COMM. DWG
ELEV. SHOWN ARE BOSTON CITY BASE



ER LINE DIKES NOS 2 AND 3

HAYDEN HARRING B. BUCHANAN, INC. CONSULTING ENGINEERS BOSTON, MASSACHUSETTS		U.S. ARMY ENGINEER CORPS OF ENGINEERS WALTHAM, MASS.	
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS NORUMBEGA RESERVOIR DAM DIKES NO. 2 & 3 PROFILE			
WESTON		MASSACHUSETTS	
		KCA E. NOT TO SCALE	
		DATE FEBRUARY 1980	

APPLY COMM. DWG DATED FEB 1, 1944
 SE

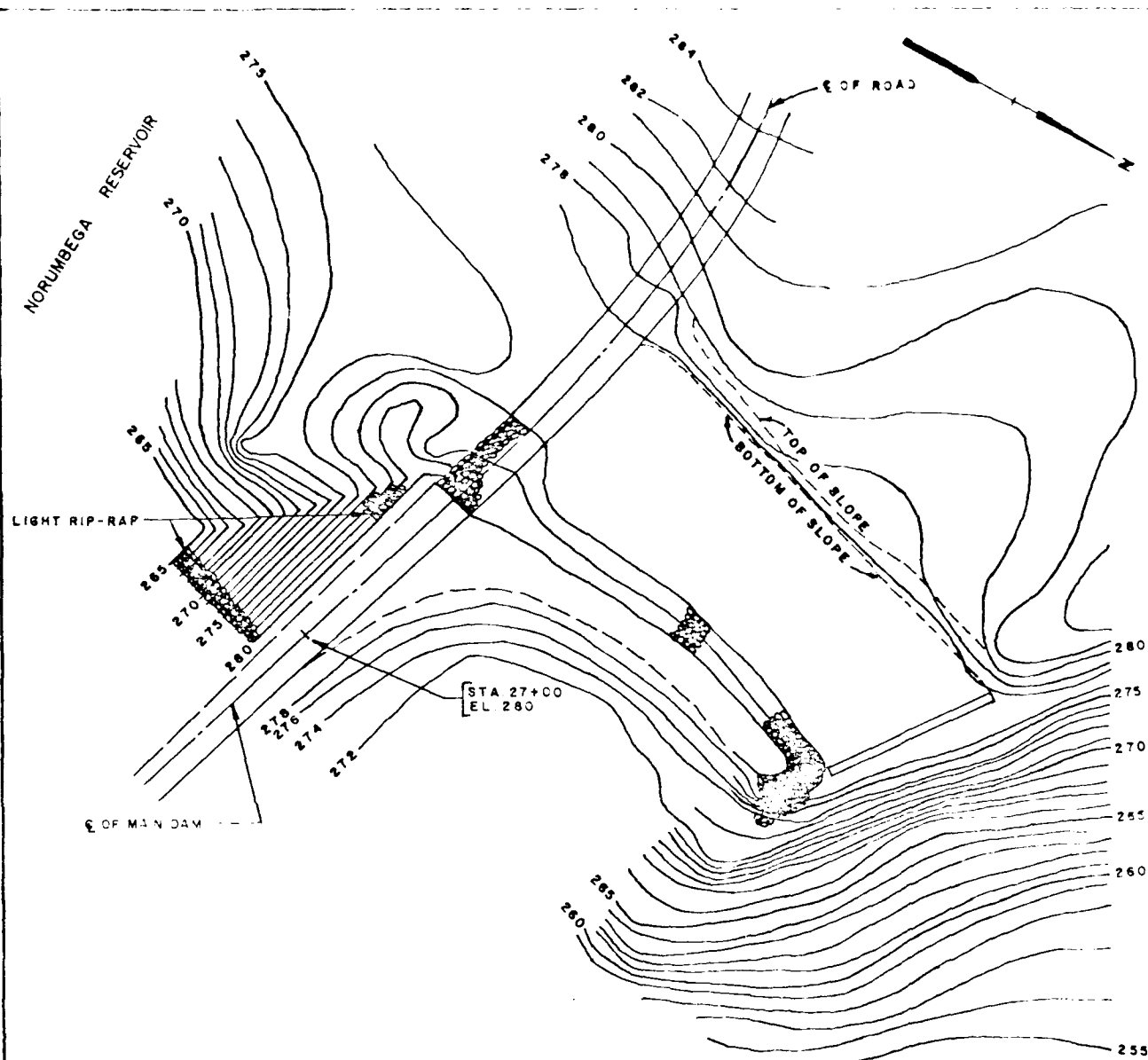


PROFILE ON CENTER LINE DIKE NO. 4

NOTE:

TAKEN FROM METR. DIST. WATER SUPPLY COMM. DWG. DATED FEB. 1, 1944
ELEVATION SHOWN ARE BOSTON CITY BASE

JAMES H. HARRIS & BUCHANAN, INC. CONSULTING ENGINEERS BOSTON, MASSACHUSETTS		J.B. ARMITAGE & CO., NEW ENGL. CORP. OF ENGINEERS WESTON, MASS.	
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS			
NORUMBEGA RESERVOIR DAM			
DIKE NO. 4			
PROFILE			
WESTON		MASSACHUSETTS	
B-7		FEBRUARY 1980	



NOTE:

TAKEN FROM METR. DIST. WATER SUPPLY COMM. DWG. DATED FEB. 1, 1944
ELEVATION SHOWN ARE BOSTON CITY BASE

HAYDEN, HARDING & BUCHANAN, INC.
CONSULTING ENGINEERS
BOSTON, MASSACHUSETTS

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

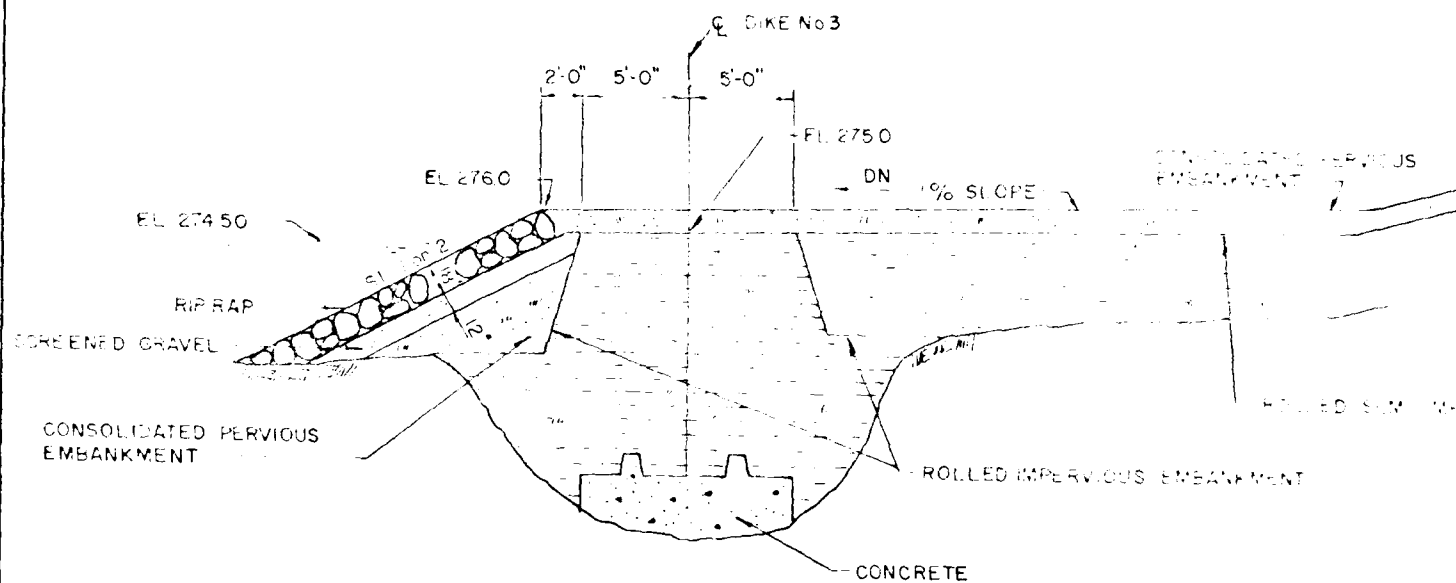
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

NORUMBEGA RESERVOIR DAM PLAN OF SPILLWAY

WESTON

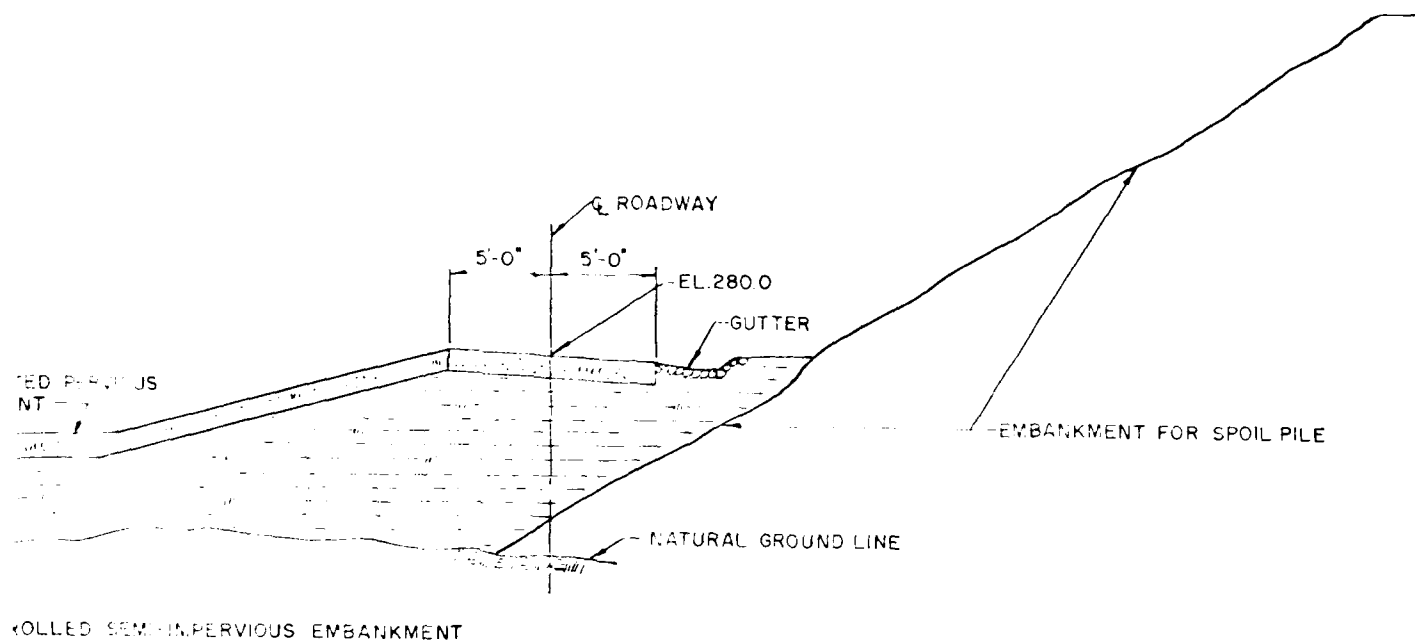
MASSACHUSETTS

SCALE NOT TO SCALE
DATE FEBRUARY 1980



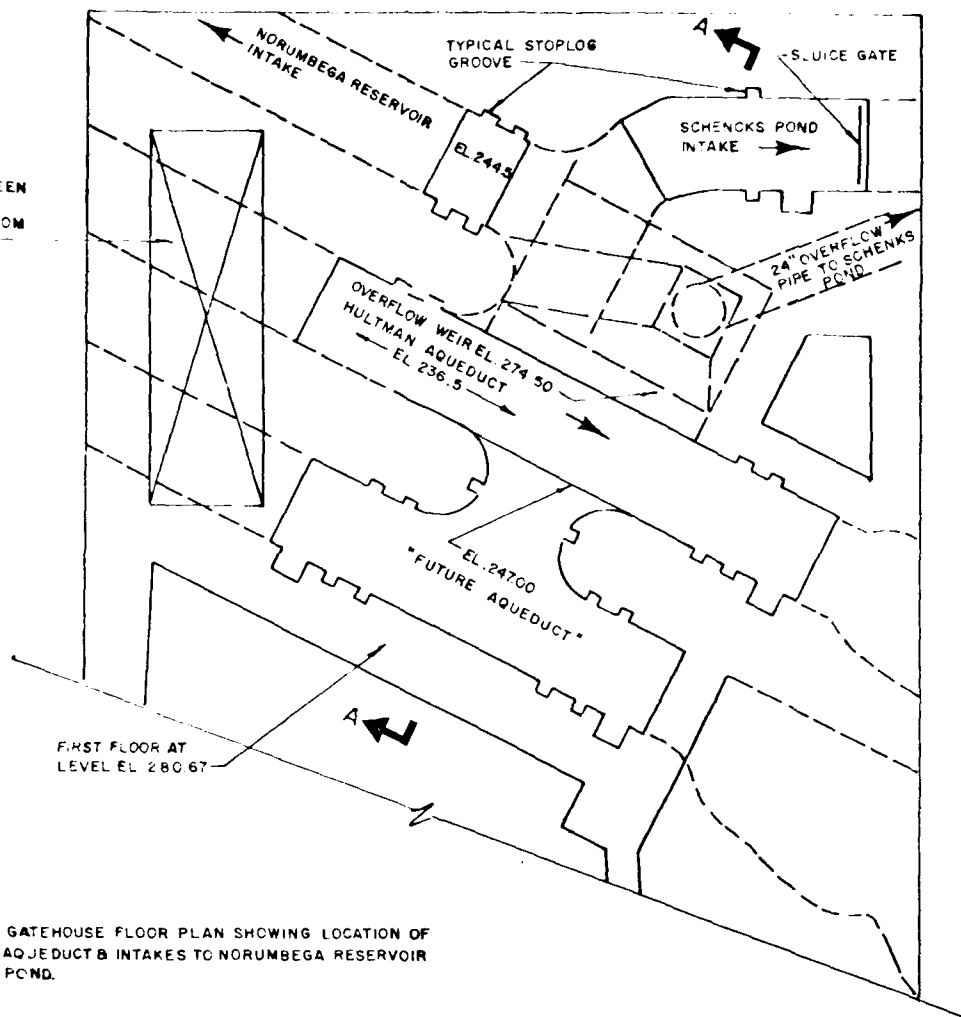
SECTION

NOTE TAKEN FROM MDC WATER SUPPLY COMM
 DWG DATED FEB 1 1944 ELEVATIONS SHOWN
 ARE BOSTON CITY BASE



HAYDEN, HARDING & BUCHANAN, INC. CONSULTING ENGINEERS BOSTON, MASSACHUSETTS		U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.	
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS			
NORUMBEGA RESERVOIR DAM SECTION THROUGH DIKE No 3			
WESTON		MASSACHUSETTS	
		SCALE NOT TO SCALE	
		DATE FEBRUARY, 1980	

STOPLOG & SCREEN
STORAGE RACK
ACCESSABLE FROM
FIRST FLOOR



PARTIAL GATEHOUSE FLOOR PLAN SHOWING LOCATION OF
HULTMAN AQUEDUCT & INTAKES TO NORUMBEGA RESERVOIR
SCHENCK POND.

PARTIAL PLAN

NOTE:

TAKEN FROM METR DISTR WATER SUPPLY COMM. DWS DATED FEB
ELEVATION SHOWN ARE BOSTON CITY BASE



DATE FEBRUARY, 1980

M.M. DWG DATED FEB. 1, 1944

INSPECTION REPORT - DAMS AND RESERVOIRS

OK
FILE 2K7

(2.) Location: City/Town Weston

Dam No. 4-4-333-2

Name of Dam WUMBEGA Res. Dam

Inspected by: D. Kilpatrick

Date of Inspection 1-7-74

(2.) Owner/s: per: Assessors _____

Prev. Inspection _____

Reg. of Deeds _____

Pers. Contact ✓

1. M. D. Ly 133 HOLLIS ST, Framingham MASS. 972-4389
Name St. & no. City/Town State Tel. no.
-01701

2. _____
Name St. & no. City/Town State Tel. no.

3. _____
Name St. & no. City/Town State Tel. no.

(3.)

Caretaker: (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Francis Birmingham Oak St. Weston - Foreman
Name St. & no. City/Town State Tel. no.

(4.)

No. of Pictures taken 0

(5.)

Degree of Hazard: (if dam should fail completely)*

1. Minor _____

2. Moderate ✓

3. Severe _____

4. Disastrous _____

* This rating may change as land use changes (future development)

(6.)

Outlet Control: Automatic ✓

Manual _____

Operative _____ yes ;

No.

Comments: Only outlet, pumping station into
distribution lines

(7.)

Upstream Face of Dam:

Condition:

1. Good ✓

2. Minor Repairs _____

3. Major Repairs _____

4. Urgent Repairs _____

Copy available to DTIC does not permit fully legible reproduction

Comments: _____

B-11

-2-

DAM NO. 4-9-777-2

- (8) Downstream Face of Dam: Condition: 1. Good ☒ 2. Minor Repairs _____
3. Major Repairs _____ Urgent Repairs _____

Comments: _____

- (9) Emergency Spillway: Condition: 1. Good _____ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments: No emergency spillway as such. In the event
at high water, water overflows low area at foot
of reservoir into rural, wooded area.

- (10) Water level @ time of inspection 16 ft. above _____ below ☒
top of dam ☒ Principal spillway _____
other _____

- (11) Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment _____
Animal Burrows and Washouts _____
Damage to slopes or top of dam _____
Cracked or Damaged Masonry _____
Evidence of Seepage _____
Evidence of Piping _____
Erosion _____
Leaks _____
Brush and/or debris impeding flow _____
Clogged or blocked spillway _____
Other _____

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permit fully legible reproduction

(20) Remarks & Recommendations: (Fully Explain)

DAM IS IN GOOD CONDITION

(20)

Overall Condition:

1. Safe ✓
2. Minor repairs needed _____
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impounded and no longer exists (expl in _____)

Recommended removal from inspection list _____

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permit fully legible reproduction

DESCRIPTION OF DAM
DISTRICT 4

Submitted by D. K. Ipatovsk
Date 1-7-74

Dam No. 4-9-333-2
City/Town Weston
Name of Dam Marquette Res. Dam

Location: Section 26 D
Provide 8 1/2 x 11 in clear copy of topo map with location of Dam clearly indicated.

Year built 1940 Year/s of subsequent repairs _____

Purpose of Dam: Water Supply ☒ Recreational
Irrigation _____ Other _____

Damage to land 135 Sq. mi. 86.5 acres.

Impoundment: 50 acres; Ave Depth 9'
Impoundment: 150 Mtlgals; 450 acre ft.

Is there any other buildings located adjacent to pond or reservoir _____

Is there any other structures 1-M.D.C. Pumping House
1-M.D.C. chlorine storage house

Dimensions of Dam: Length 2100 FT. Max. Height 25'
Slopes: Upstream Face 2:1
Downstream Face 2:1
Width across top 20 FT.

Classification of Dam by Materials:

Concrete ☒ Stone Masonry _____
Masonry _____ Rockfill _____ Other _____

1. Severity of present land usage downstream of dam: 90 % rural;
10 % urban

2. Is there a storage area or flood plain downstream of dam: which could
be used for the impoundment in the event of a complete dam failure

Yes

Copy available to DTIC does not
permit fully legible reproduction

DATE NO. 4-9-333-2

20.

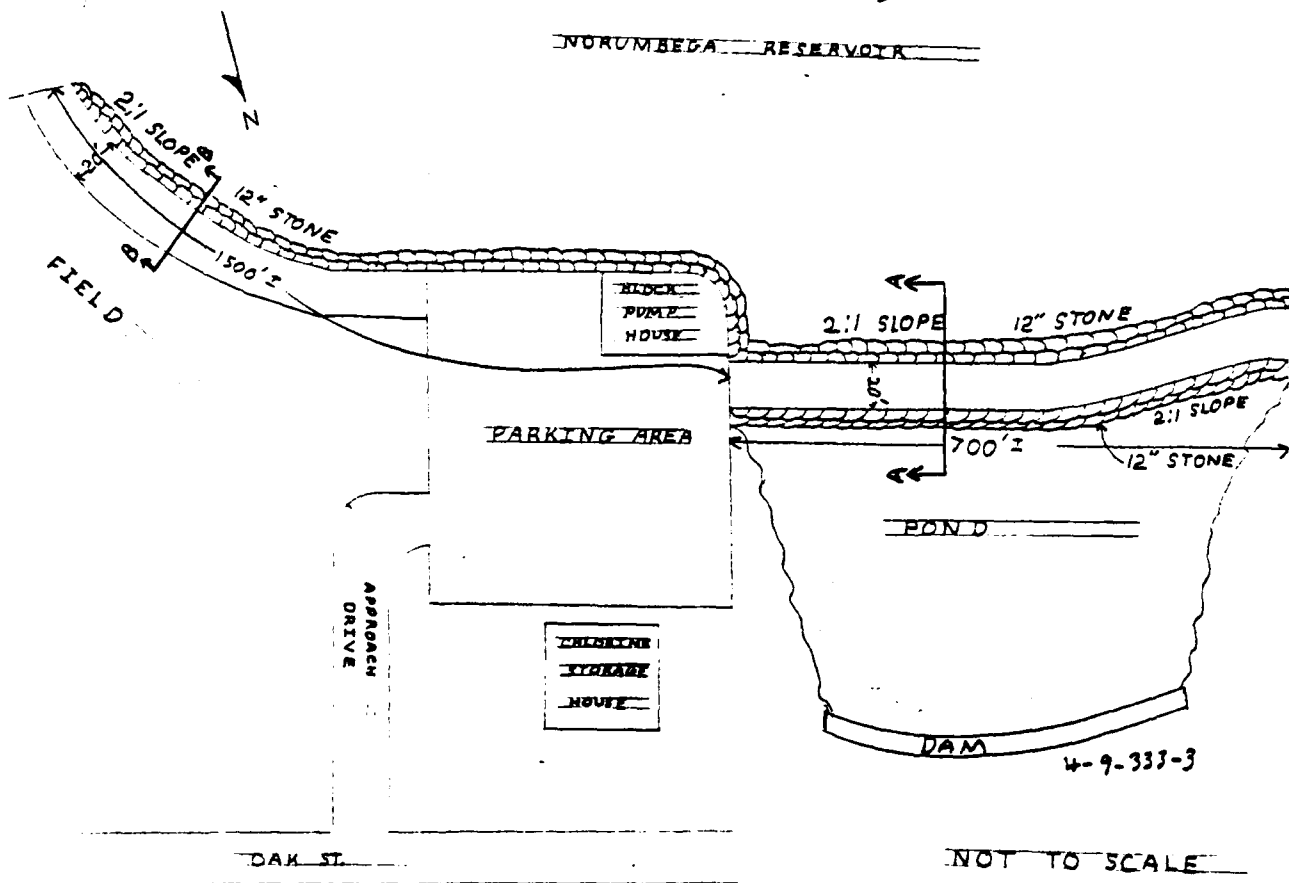
Risk no life and property in event of complete failure.

No. of people 27
No. of horses 9
No. of businesses None
No. of automobiles 11
No. of utilities One
Railroads _____
Other farm ONE
Other _____

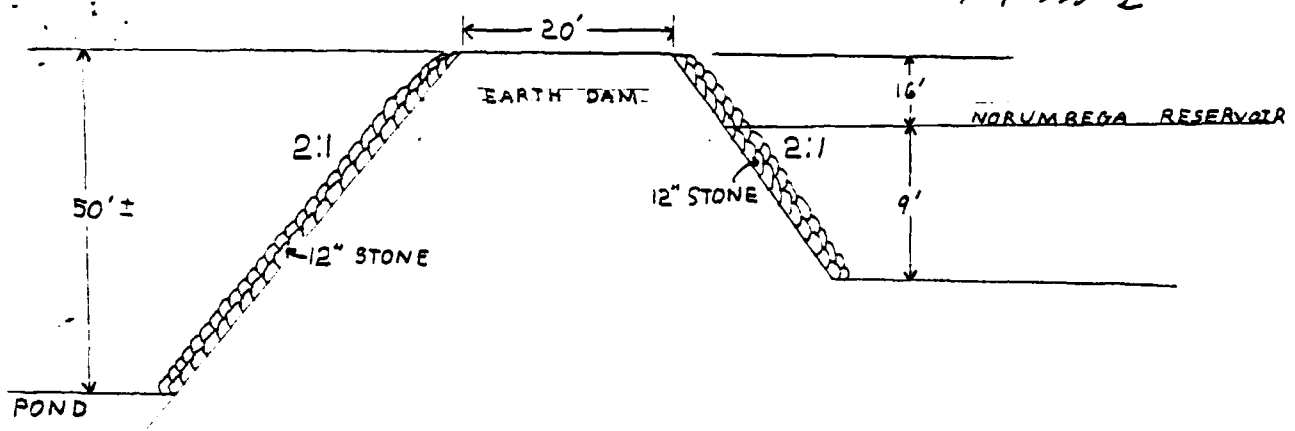
Type M.D.C. water supply line

2000

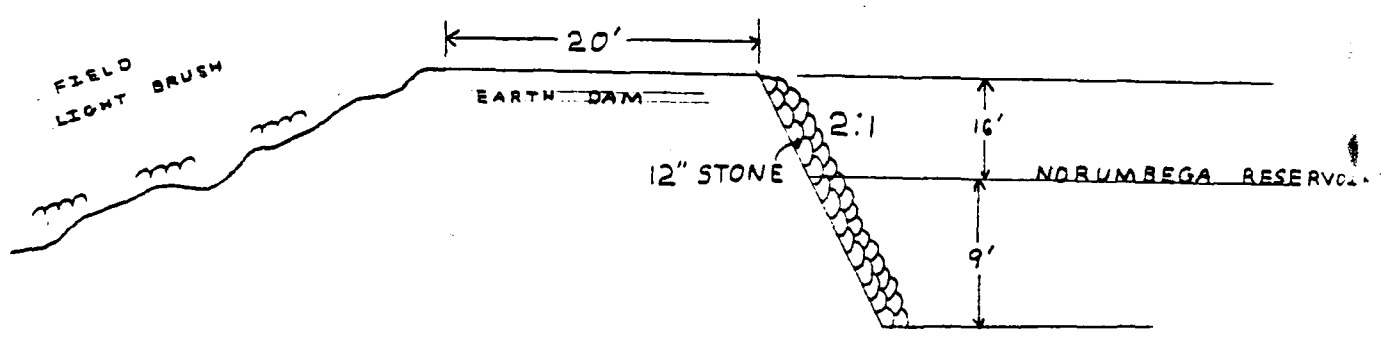
Attach sketch of cam to this form showing section and plan 8½" x 11" Sheet.



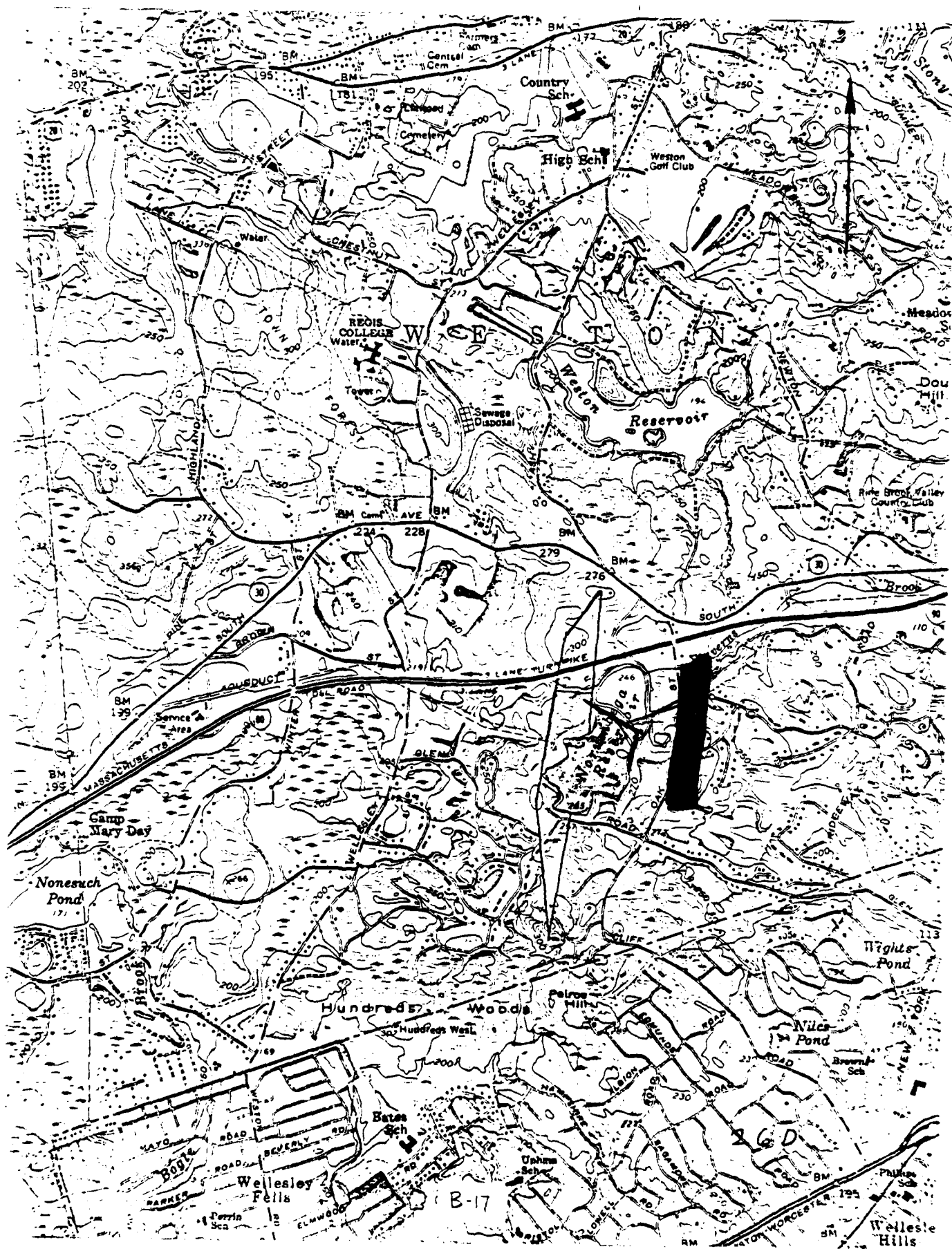
4-9-335-2



SECTION A-A



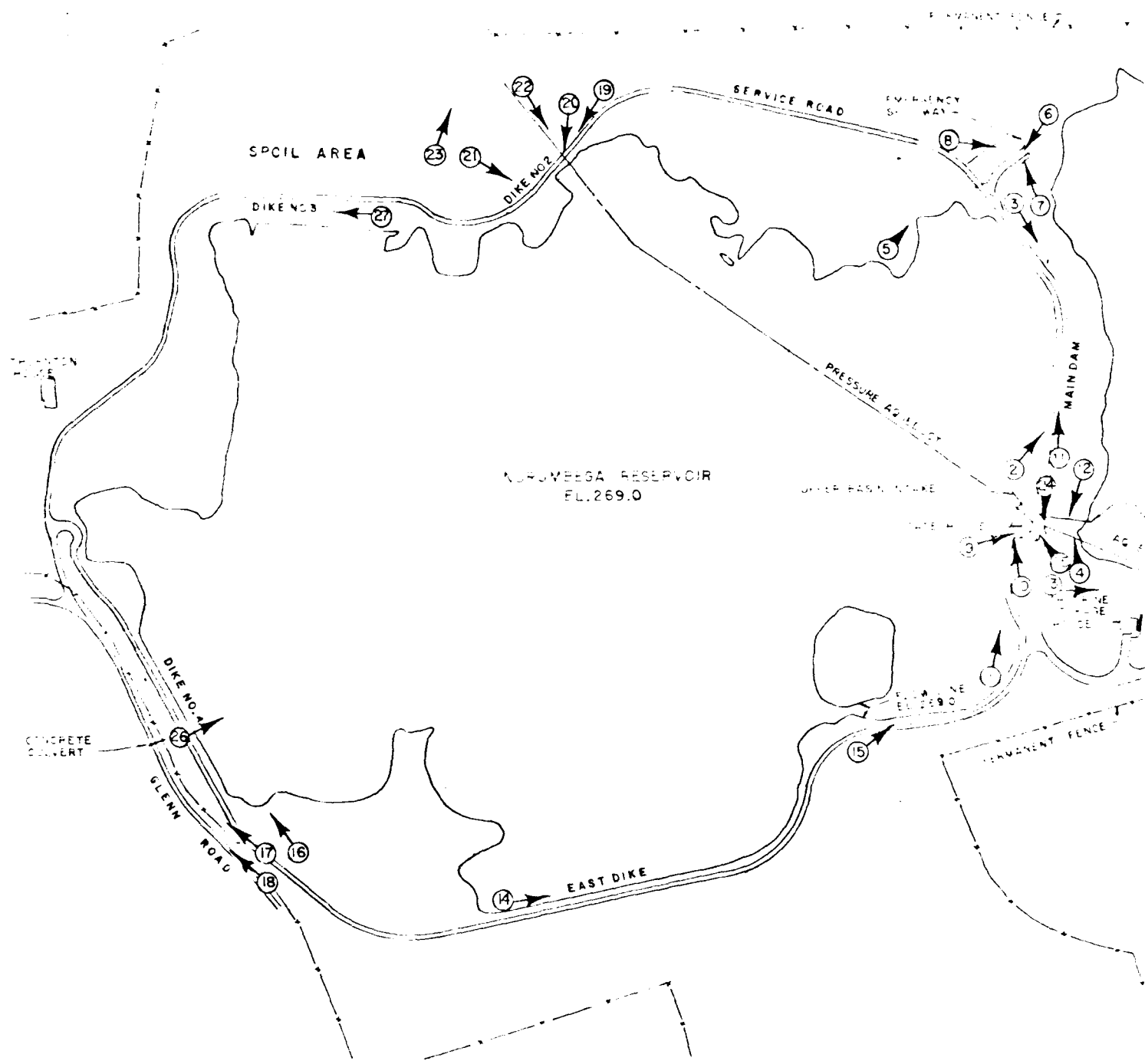
SECTION B-B



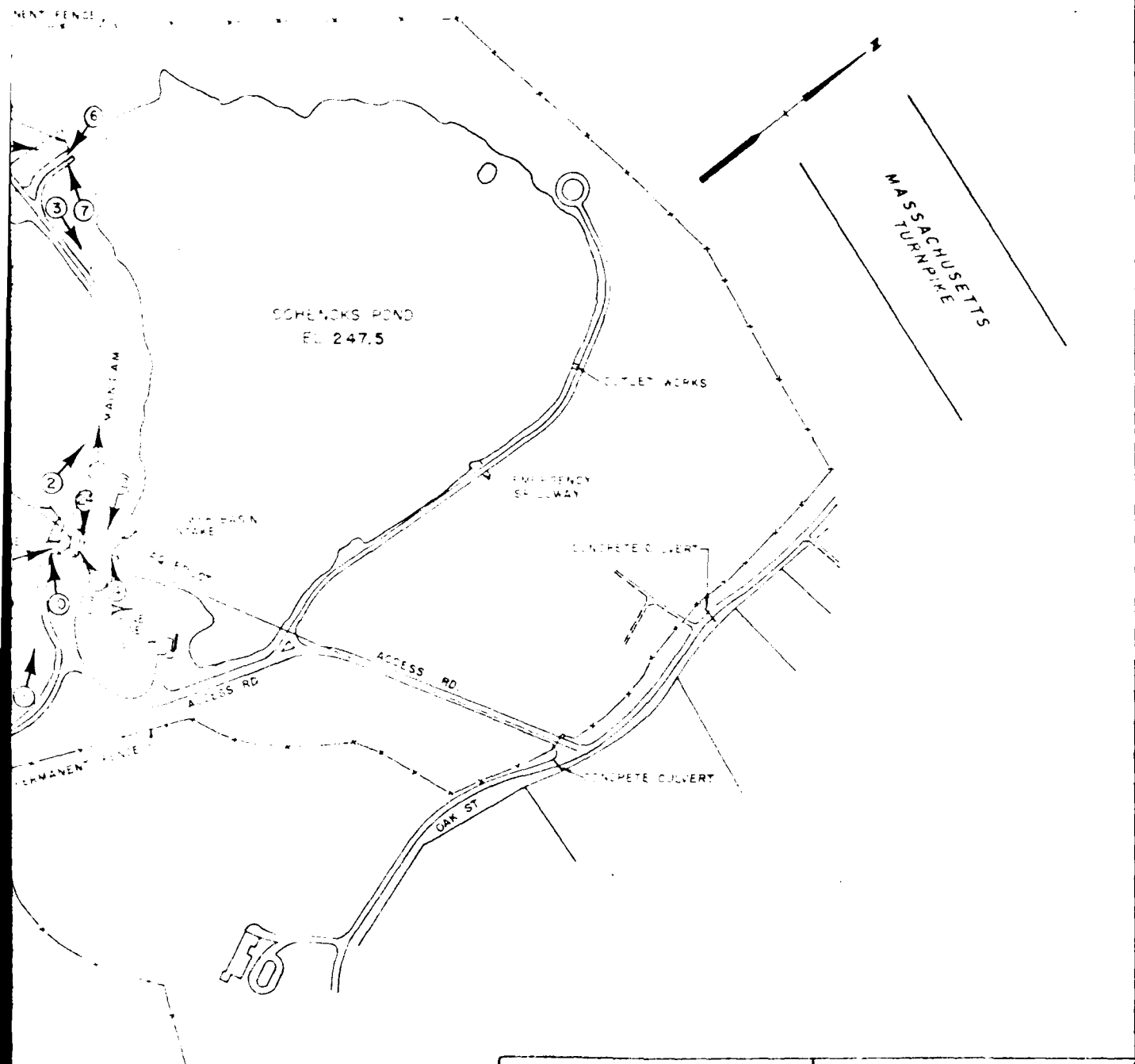
APPENDIX C
PHOTOGRAPHS

C-1

Norumbega Reservoir Dam & Dikes



NOTE:
TAKEN FROM METR. DIST. WATER SUPPLY COMM. DWS DATED MAY 7
ELEVATION SHOWN ARE NGVD



HAYDEN, HAROLD B. BUCHANAN, INC. CONSULTING ENGINEERS BOSTON, MASSACHUSETTS		U.S. ARMY ENGINEER ON NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.	
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS			
NORUMBEGA RESERVOIR DAM PHOTO LOCATIONS			
WESTON		MASSACHUSETTS	
		SCALE NOT TO SCALE	
		DATE FEBRUARY 1980	

CWS DATED MAY 3, 1941



PHOTO NO. 1 - Upstream slope of Dam as viewed from
the East Dike.



PHOTO NO. 2 - Upstream slope of
Dam as viewed from right
abutment area near gatehouse.



PHOTO NO. 3 - Downstream slope of Dam as viewed from left
abutment area.



PHOTO NO. 4 - Downstream slope of Dam as viewed from right
abutment area near gatehouse.



PHOTO NO. 5 - Spillway as viewed from upstream end.



PHOTO NO. 6 - Right spillway
wall as viewed from down-
stream end.



PHOTO NO. 7 - Spillway crest consisting of 18 inch wide concrete wall as viewed from right side.

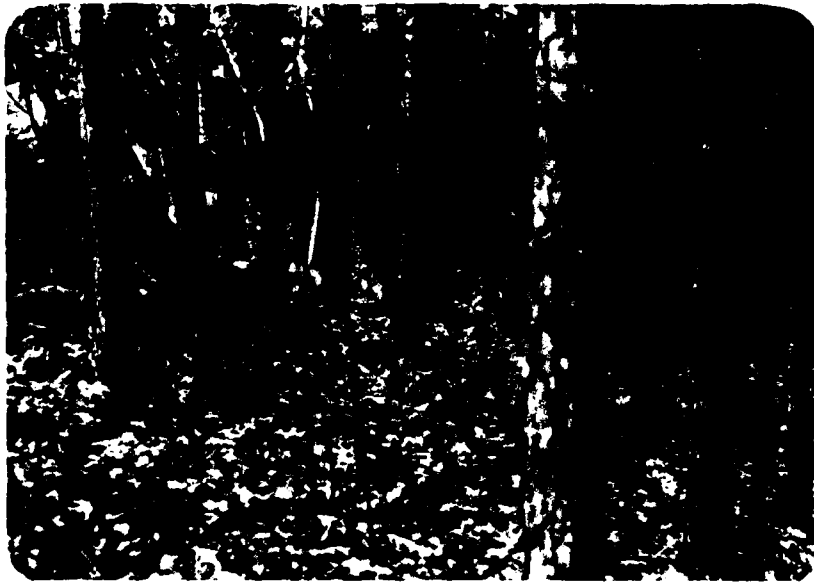


PHOTO NO. 8 - Spillway discharge area as viewed from the right side of the spillway.



PHOTO NO. 9 - Eroded area on
upstream slope of Dam right
of the gatehouse as viewed
from bottom of slope; scale
open to 6 feet.

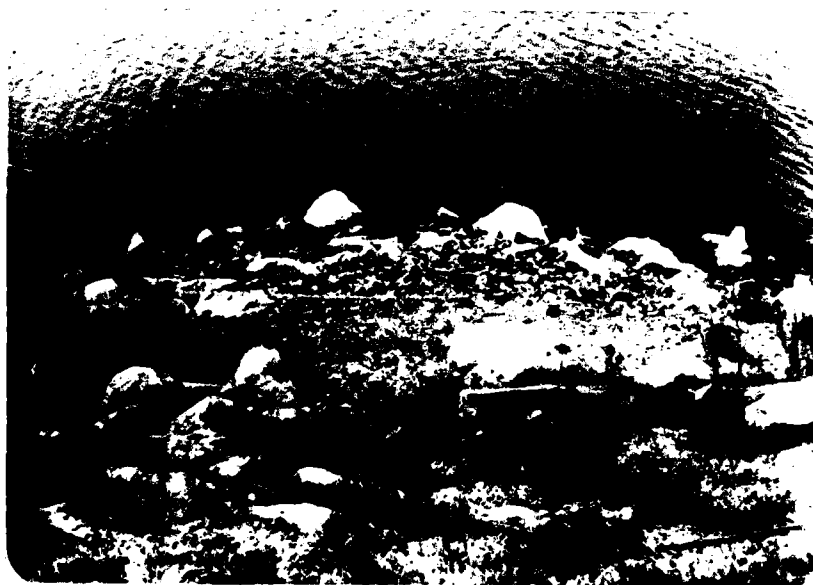


PHOTO NO. 10 - Eroded area on upstream slope shown in Photo No. 9
as viewed from the crest; scale open to 6 feet.



PHOTO NO. 11 - Crest of Dam as viewed from right abutment area near gatehouse.

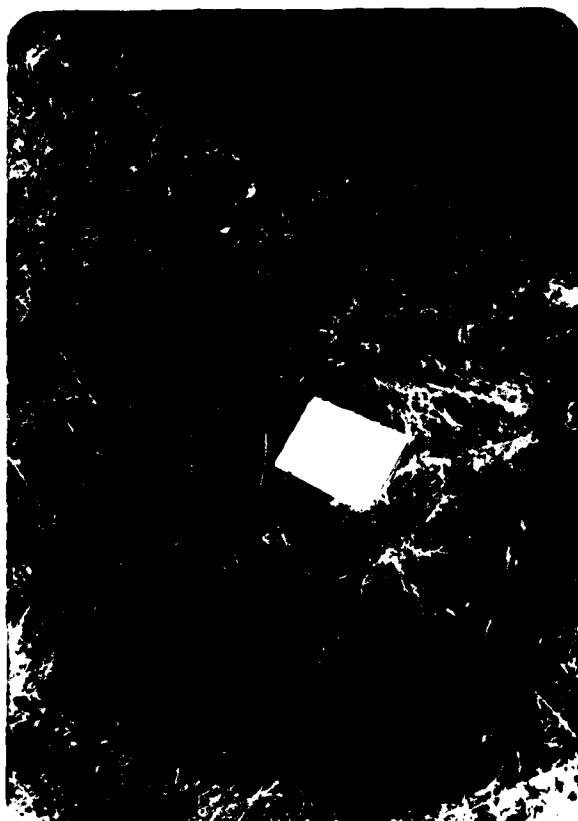


PHOTO NO. 12 - Eroded area on downstream slope of Dam near the gatehouse.



PHOTO NO. 13 - Runoff channel
on downstream slope of Dam
near the gatehouse.



PHOTO NO. 14 - General view of the East Dike
from the right abutment area.



PHOTO NO. 15 - General view of East Dike looking
toward gatehouse.



PHOTO NO. 16 - Upstream slope
of Dike 4 as viewed from
left abutment area.



PHOTO NO. 17 - Downstream slope
and portion of crest of Dike
4 as viewed from left abut-
ment area.



PHOTO NO. 18 - Downstream area of Dike 4 as viewed from left
abutment area.



PHOTO NO. 19 - Crest of Dike 2 as viewed from right abutment area.



PHOTO NO. 20 - Upstream slope of Dike 2 as viewed from right abutment area.



PHOTO NO. 21 - Downstream slope of Dike 2 as viewed from
about 50 feet downstream of toe.

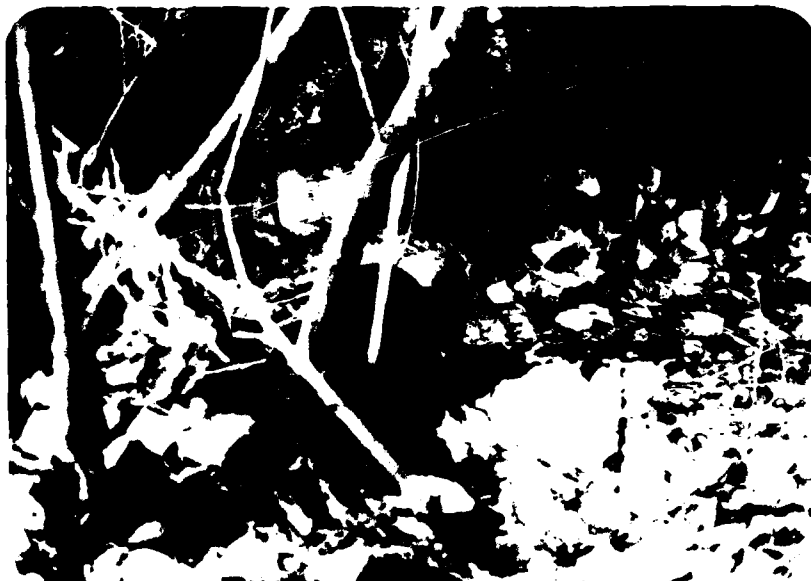


PHOTO NO. 22 - View of clay pipe in drainage ditch on down-
stream, left side of Dike 2.



PHOTO NO. 23 - Drainage ditch on downstream, left side of Dike 2 looking toward the dike; this photo was taken downstream of the clay pipe shown in Photo No. 22.



PHOTO NO. 24 - Separation of asphalt paving from the downstream wall of the gatehouse; also pipe entering asphalt paving at the left side of the wall.



PHOTO NO. 25 - Pipe entering asphalt paving at the right side of the downstream wall of the gatehouse.

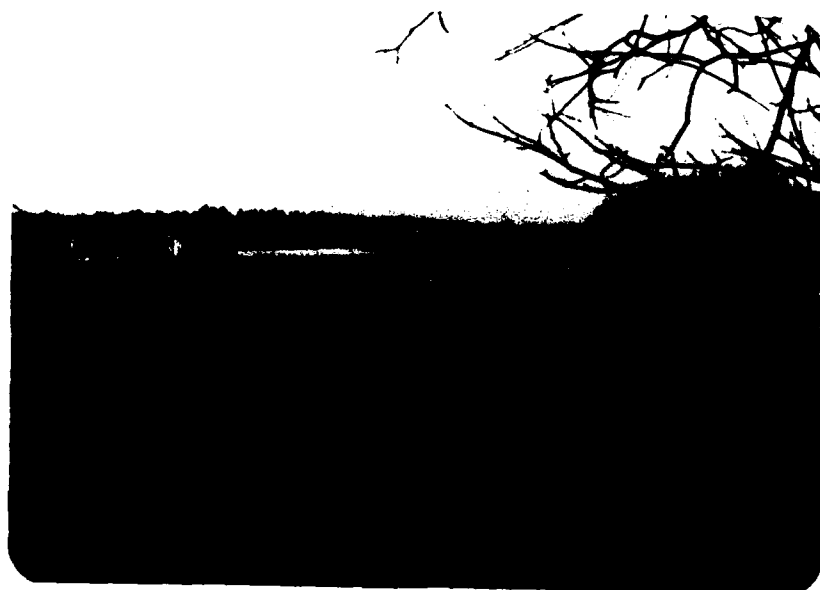


PHOTO NO. 26 - View of reservoir taken from Dike 4 upstream slope of Main Dam in background.



PHOTO NO. 27 - View of Dike No. 3. Roadway is at the toe of the embankment for spoil area as shown in Appendix B. Drawing on page B-9.

APPENDIX D
HYDROLOGIC AND HYDRAULIC COMPUTATIONS

AD-A155 742

NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
MORMONGA RESERVOIR D. (U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV MAR 80

2/2

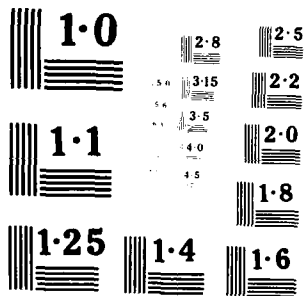
UNCLASSIFIED

F/G 13/13

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END
DATE
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8-85
DTH

END
DATE
FILMED
8-85
DTIC



JOB NO. 79.206.1
DATE 12/14/79
BY FDD
CHK'D BY VHA

HH & B HAYDEN, HARDING & BUCHANAN, INC.
CONSULTING ENGINEERS
BOSTON — WEST HARTFORD

SHEET NO. 22
JOB Dam
SUBJECT Norumbega Reservoir
CLIENT Corps

Norumbega Reservoir Dam - built 1940-1944

Height of Main Dam: 25' ✓

Height of Dikes: 15' ✓

Water flows towards main dam to intake structure for aqueducts and lower pond (Schenck Pond). Norumbega & Schenck Reservoirs serve as pump storage facilities for the MDC water supply system.

Storage Capacity: 500⁺ ac-ft.

Size Class: Small (by Storage & Height)

Drainage area: 0.10 s.m. = 63 acres ±

Hazard Potential: High

Test Flood: 1/2 PMF to Full PMF: developed use Full PMF

Inflow = 3000 csm × 0.10 sm × 1.0 = 300-fs ✓

PMF Outflow ≈ 160 cfs, Flow 272.8

Spillway will pass entire PMF Outflow and 1/2 PMF outflow

JOB NO. 79.206.1
 DATE 12/5/79
 BY DD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

SHEET NO. D-2a
 JOB Dams
 SUBJECT Norumbega
 CLIENT Corps

Storage Capacity

Elev. ft	Area acres	Ave. Area ac	D ft	Storage ac-ft	Accum Stor. ac-ft
(USGS)					
260	11.0	-	-	-	-
265	34.0 ✓	22.5 ✓	5 ✓	112.5 ✓	112.5
270	41.4	37.7 ✓	5 ✓	198.5 ✓	301.0 ✓
274.4	49.6 ✓	45.5 ✓	4.4	200.2 ✓	501.2 ✓

Test Flood

Have High Hazard & Small Size: Test
 Flood range: 1/2 to Full PMF. As have several
 flow paths which could damage a number of
 homes & possibly loss of life, use Full PMF.

$$Q_{\text{inflow}} = 3000 \text{ cfs} \times 0.11 \text{ m} \times 1 = 300 \text{ cfs} \checkmark$$

$$Vol_{\text{in}} = 19 \text{ in} \times 63 \text{ ac} \times \frac{1 \text{ ft}}{12 \text{ in}} = 100 \text{ ac-ft} \checkmark$$

Reservoir is a pump storage facility with
 normal maximum high water at elevation 269, spill stor
 269 to 271.4 (spillway) = 115 ac-ft, From 271.4 to 274.4 = 135 ac-ft
 From 269 to 271.4 could retain entire inflow.

Thus under normal operating conditions, could
 store all PMF Inflow without overtopping
 structures.

JOB NO. 79.206.1
 DATE 12/5/79
 BY FDD
 CH'D BY MA

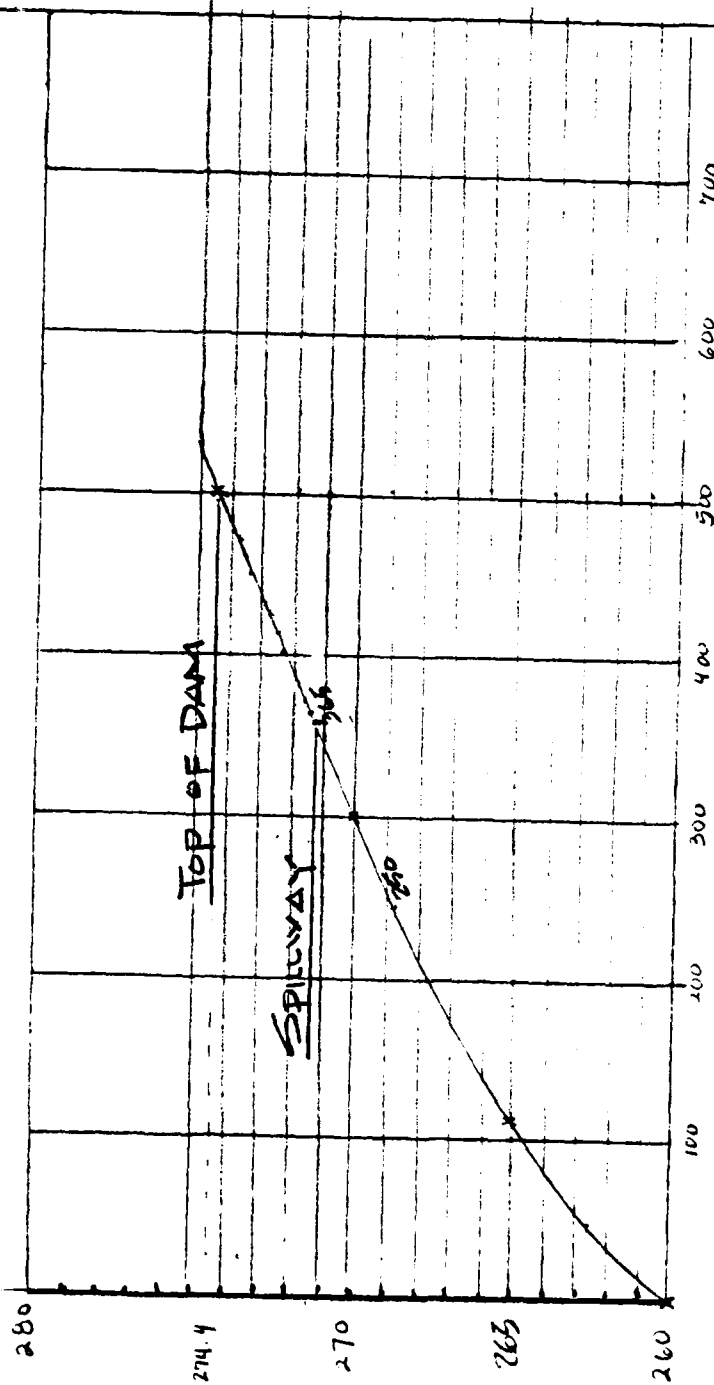


HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

JOB Dam SHEET NO 2-3
 SUBJECT Norumbega
 CLIENT C&P

Stage - Storage

Elevation Ft USGS (MSL)



Storage, ac.-ft

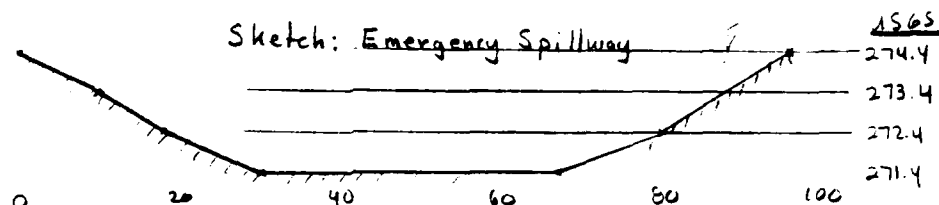
USGS BCB - 5.5'

JOB NO. 79.206.1
 DATE 12/6/79
 BY FDD
 CH'D BY AK

HH & B HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

SHEET NO. 4
 JOB Dams
 SUBJECT Narumbege Res.
 CLIENT Corps

Dam has "emergency spillway" located to NW of Gate Howe: "Spillway" actually overflow to Shencks Pond at low point of roadway.



Assume "Spillway" acts as Broad-crested weir

$$L = 37' \pm \quad C = 2.6$$

$$\text{Use } Q = CLH^{3/2}$$

$\frac{H}{ft}$	$\frac{C}{}$	$\frac{L}{ft}$	$\frac{Q}{cfs}$	Elev (USGS)
1	2.6	37	96	272.4
2	"	"	272	273.4
3	"	"	500	274.4 Top of Dam

"Emergency Spillway" would be able to pass full PMF Inflow without overtopping dam $Q_{in} = 300 \text{ cfs}$

Summarizing: Under normal condition (reservoir water level below elevation 271.4), reservoir could "store" entire PMF Inflow without spillway discharge. For elevations above this level, "emergency spillway" could handle PMF Outflow. Also, the intake to the gate howe, if opened, could provide a considerable amount of additional discharge capacity.

★ Thus: Structure (dams/dikes) will not be overtopped by Test Flood

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DATE 12/14/79
BY EDD
CHK'D BY MA

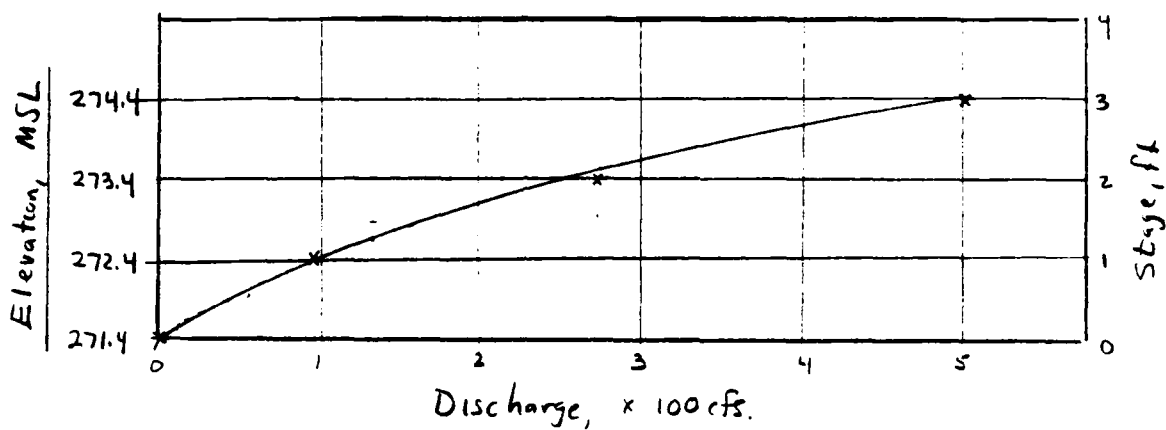


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BOSTON — WEST HARTFORD

SHEET NO. D-5

JOB Dam
SUBJECT Narumanga Res.
CLIENT Corps

Elevation vs. Discharge for Emergency Spillway



Top of Dam Elevation: 274.4 ±
Invert "Emergency" Spillway: 271.4 ±

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SHEET NO. 2.5a
JOB DAMS
SUBJECT Norumbega
CLIENT CoE

Test Flood Outflow

from spillway only, into Schenks Res

$$Q_I = 300 \text{ cfs} \quad H_1 = 273.6$$

$$S_{tor,1} = 450 - 365 = 95 \text{ a-f or } 18.10''$$

$$Q_{P_2} = 300 \left(1 - \frac{18.10}{19} \right) = 14 \text{ cfs}$$

$$H_2 = 271.6 \quad S_{tr,2} = 370 - 365 = 5 \text{ a-f or } 0.95''$$

$$S_{trave} = 9.53''$$

$$Q_{P_3} = 300 \left(1 - \frac{9.53}{19} \right) = 150.5 \text{ cfs}$$

discharge Elev. = 272.8

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SHEET NO. 2-5b
JOB Dams
SUBJECT Nacumbege Res
CLIENT Corps

Check Storage Routing for 1/2 PMF:

$$Q_{1/2 PMF} = 3000 \times 0.10 \times 1/2 = 150 \text{ cfs} \checkmark$$

$$Vol_{1/2 PMF} = 19 \times \frac{1}{12} \times 63 \times 1/2 = 50.0 \text{ ac-ft} \checkmark$$

$$Q_{P_1} = 150 \text{ cfs} \checkmark \quad Elev_1 = 272.8 \pm$$

$$Stor_1 = 430 - 365 = 65 \text{ ac-ft} \checkmark \text{ or } 11.5 \text{ in} \checkmark$$
$$Stor_1 = 11.5 \rightarrow 9.5 \text{ in for } 1/2 PMF$$

$$Stor_{ave} = \frac{0 + 11.5}{2} = 5.75 \text{ in}$$

$$Q_{P_2} = 150 \left(1 - \frac{5.75}{9.5}\right) = 59 \text{ cfs} \checkmark \quad Elev_2 = 272.1 \pm$$

$$Stor_2 = 394 - 365 = 29 \text{ ac-ft} \text{ or } 5.11 \text{ in}$$

$$Stor_{ave} = \frac{5.75 + 5.11}{2} = 5.43 \text{ in}$$

$$Q_{P_3} = 150 \left(1 - \frac{5.43}{9.5}\right) = 64 \text{ cfs} \quad Elev_3 = 272.1 \pm$$

$$Q_{out} = 65 \pm \text{cfs} \quad Elev = 272.1 \pm$$

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SHEET NO. D-6
JOB Dams
SUBJECT Norembege Res.
CLIENT Corps

Failure Discharge

① Assume Main Dam Fails [Dam #1]

$$Q_F = \frac{8}{27} \times (0.4 \times 445) (\sqrt{32.2}) (25)^{3/2}$$

$$Q_F = 37,380, \text{ cfs.}$$

✓ Base Flow

$$Q_T = Q_F + Q_B = 37,380 + 500 = 37,900 \text{ cfs.}$$

② Assume portion of Dike fails (2 possible locations)
(See page 26)

a. Dike along Glen Road: "South Dike" $3/2$ [Dam #4]

$$Q_F = \frac{8}{27} \times (0.4 \times 200) (\sqrt{32.2}) (15)^{3/2}$$

$$Q_F = 7,814, \text{ cfs.} \checkmark$$

b. Dike along Western side of Reservoir at agreed: "West D." $3/2$

$$Q_F = \frac{8}{27} \times (0.4 \times 200) (\sqrt{32.2}) (15)^{3/2} \quad [\text{Dam \#2-3}]$$

$$Q_F = 7,814, \text{ cfs.} \checkmark \quad (\text{See Page 37})$$

③ For Failure of Main Dam: Failure Outflow goes directly into Schencks Reservoir. Schencks Reservoir does not have capacity to store and/or pass this flow. Failure Outflow will overtop Schencks Pond Dam & continue downstream.

With overtopping Schencks Res. Dam could fail, also.

IF assume Reservoir full before Norembege fails its failure would increase outflow by approx 17,100 cfs. (by Corps Guidelines)

Combined Total Failure outflow now: 55,500 cfs

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SHEET NO. D-7
 JOB Dams
 SUBJECT Norumbega Res.
 CLIENT Corps

Sta. 14+00 below Norumbega Reservoir
 (= 5+00± below Schenck Reservoir)

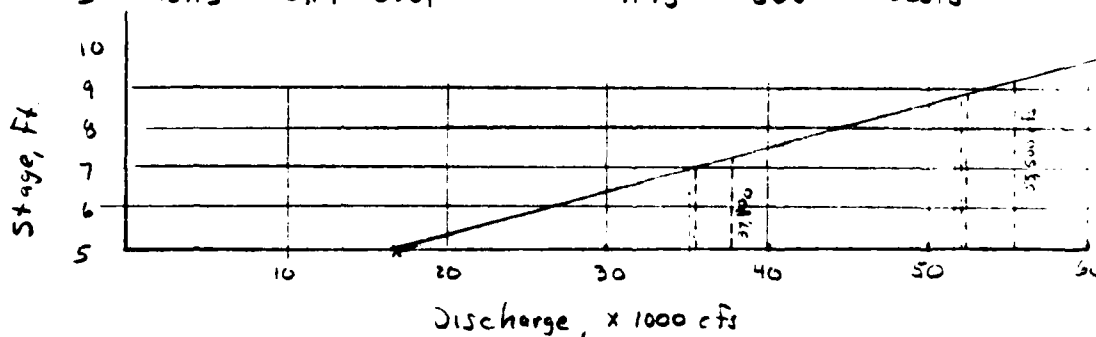
Assume culverts through Oak St Road Embankment blocked
 or too small — all flow will be over road.

channel slope, $S = \frac{10'}{400} = 0.025'$ $n = 0.10$ (heavy brush & trees)

$V = \frac{1.486}{n} R^{2/3} S^{1/2}$ $F' = \frac{1.486}{0.10} (0.025)^{1/2} = 2.35'$

$V = F' R^{2/3} = 2.35 R^{2/3}$

$\frac{D}{ft}$	$\frac{WP}{ft}$	$\frac{A}{sf}$	$\frac{R^{2/3}}$	$\frac{F'}{ft}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{Elev}{ft \pm MSL}$
10	1,150	7,550	3.53	2.35	8.29	62,600	240
5	775	2938	2.44	"	5.74	16,859	235
1	475	437.5	0.95	"	2.22	973	231
0.5	437.5	209.4	0.61	"	1.43	300	230.5



① $Q_p = 55,500 \pm cfs$ - Combined Failure of
 Norumbega & Schenck Reservoirs

② $Q_p = 37,900 \pm cfs$

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SHEET NO. D-2
 JOB Dams
 SUBJECT Nacumbaga Res.
 CLIENT Corps

For ① $Q_p = 55,500 \text{ cfs}$ $d_1 = 9.2'$

$$Vol_1 = \frac{1980 + 7408}{2} \times \frac{500}{43,560} = 53.88 \text{ ac-ft}$$

$$Q_{p2} = 55,500 \left(1 - \frac{53.88}{756 + 66}\right) = 51,862 \text{ cfs} \quad d_2 = 8.8$$

$$Vol_2 = \frac{1980 + 6424}{2} \times \frac{500}{43,560} = 48.23 \text{ ac-ft}$$

$$Vol_{ave} = \frac{48.23 + 53.88}{2} = 51.06$$

$$Q_{p2} = 55,500 \left(1 - \frac{51.06}{622}\right) = 52,053 \text{ cfs} \quad d_3 = 8.5'$$

$$Vol_3 = \frac{1980 + 6477}{2} \times \frac{500}{43,560} = 48.53 \text{ ac-ft}$$

$$Q_{p3} = 55,500 \left(1 - \frac{48.53}{43,560}\right) = 52,223 \text{ cfs} \quad d_3 = 8.9'$$

$$Vol_3 = \frac{1980 + 6530}{2} \times \frac{500}{43,560} = 48.84 \text{ ac-ft}$$

$$Vol_{ave} = \frac{48.53 + 48.84}{2} = 48.69 \text{ ac-ft}$$

$$Q_{p4} = 55,500 \left(1 - \frac{48.69}{622}\right) = 52,213 \text{ cfs} \quad d_4 = 8.9'$$

$$Q_{out} = 52,213 \text{ cfs} \quad Elev = 238.9'$$

For ②

$$Q_p = 37,900 \quad d_1 = 7.3'$$

Assume U.S. Area = D.S. Area
 (Same X Sect in reach ±)

$$Vol_1 = \frac{1 \times 4918}{2} \times \frac{500}{43,560} = 56.46 \text{ ac-ft}$$

$$Q_{p2} = 37,900 \left(1 - \frac{56.46}{756}\right) = 35,670 \text{ cfs} \quad d_2 = 7.0'$$

$$Vol_2 = 4638 \times \frac{500}{43,560} = 53.23$$

$$Vol_{ave} = \frac{56.46 + 53.23}{2} = 54.85 \text{ ac-ft}$$

JOB NO. 79.206.1
 DATE 12/17/79
 BY FDD
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SHEET NO. 29
 JOB Dams
 SUBJECT Norumbega Res.
 CLIENT Corpl

$$Q_{P_2} = 37,900 \left(1 - \frac{54.85}{756}\right) = 35,150 \text{ cfs } d_3 = 7.05'$$

$$Vol_3 = 4684 \times \frac{500}{43,560} = 53.76 \text{ ac-ft}$$

$$Q_{P_3} = 37,900 \left(1 - \frac{53.76}{756}\right) = 35,205 \text{ cfs } d_3 = 7.07'$$

$$Vol_3 = 4702 \times \frac{500}{43,560} = 53.98 \text{ ac-ft}$$

$$Vol_{ave} = \frac{53.76 + 53.98}{2} = 53.87$$

$$Q_{P_4} = 37,900 \left(1 - \frac{53.87}{756}\right) = 35,200 \text{ cfs}$$

$$Q_{out} = \underline{35,200 \text{ cfs}} \quad \text{Elevation} = \underline{237 \pm}$$

Sta 18+00 Below Norumbega Reservoir
 (Sta. 9+00 below Schenck's Res)

$$\text{channel slope, } S = \frac{30}{400} = 0.075\%, \quad n = 0.06$$

$$V = F' R^{2/3} \quad F' = \frac{1.486}{0.06} \times (0.075)^{1/2} = 6.78$$

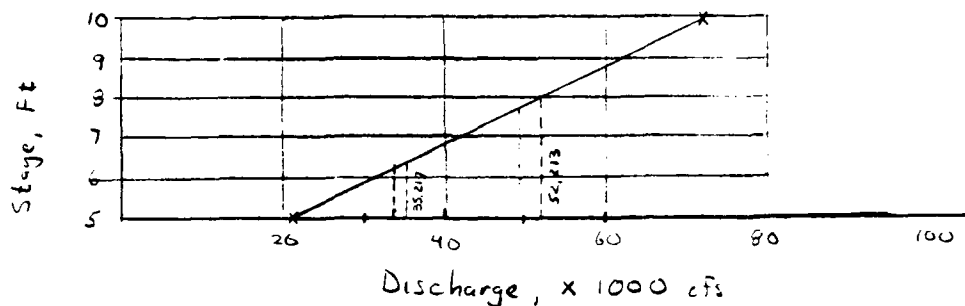
$$V = 6.78 R^{2/3}$$

$\frac{D}{ft}$	$\frac{W.P.}{ft}$	$\frac{A}{sq\ ft}$	$\frac{R^{2/3}}$	$\frac{F'}{}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{Elev}{ft\ (MSL)}$
10	32.5	262.5	4.05	6.78	27.48	72,146	210
5	262.5	1156.3	2.70	"	18.31	21,172	205
1	225	212.5	0.96	"	6.53	1397	201
0.5	212.5	106.3	0.63	"	4.26	453	200.5

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SHEET NO. D-10
 JOB Dams
 SUBJECT Norumbega Res.
 CLIENT Corpi



① $Q_p = 52,213 \text{ cfs.}$

② $Q_p = 35,200 \text{ cfs.}$

For ① $Q_p = 52,213 \quad d_1 = 9.0'$

$Vol_1 = \frac{5500 + 2000}{2} \times \frac{400}{43,560} = 39.03 \text{ ac-ft}$

$Q_{p2} = 52,213 \left(1 - \frac{39.03}{922}\right) = 49,734 \text{ cfs} \quad d_2 = 7.75'$

$Vol_2 = \frac{5500 + 1916}{2} \times \frac{400}{43,560} = 38.64 \text{ ac-ft}$

$Vol_{ave} = \frac{39.03 + 38.64}{2} = 38.83 \text{ ac-ft}$

$Q_{p3} = 52,213 \left(1 - \frac{38.83}{922}\right) = 49,746 \text{ cfs.} \quad d_3 = 7.75'$

$Q_{out} = 49,746 \text{ cfs.} \quad Elev = 207.75'$

For ② $Q_p = 35,200 \text{ cfs.} \quad d_1 = 6.4'$

$Vol_1 = \frac{4700 + 1536}{2} \times \frac{400}{43,560} = 28.63 \text{ ac-ft.}$

$Q_{p2} = 35,200 \left(1 - \frac{28.63}{756}\right) = 33,867 \text{ cfs} \quad d_2 = 6.3'$

$Vol_2 = \frac{4700 + 1508}{2} \times \frac{400}{43,560} = 28.50 \text{ ac-ft}$

$Vol_{ave} = \frac{28.63 + 28.50}{2} = 28.57 \text{ ac-ft}$

JOB NO. 79.206.1
 DATE 12/7/75
 BY FDD
 CH'D BY mt



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SHEET NO 2-11
 JOB Dam
 SUBJECT Norumbega Res.
 CLIENT Corps

$$Q_{p_s} = 35,200 \left(1 - \frac{28.57}{756}\right) = 33,870 \text{ cfs} \quad d_2 = 6.3'$$

$$Q_{wt} = \underline{33,870 \text{ cfs.}} \quad \text{Elev.} = \underline{206.3'}$$

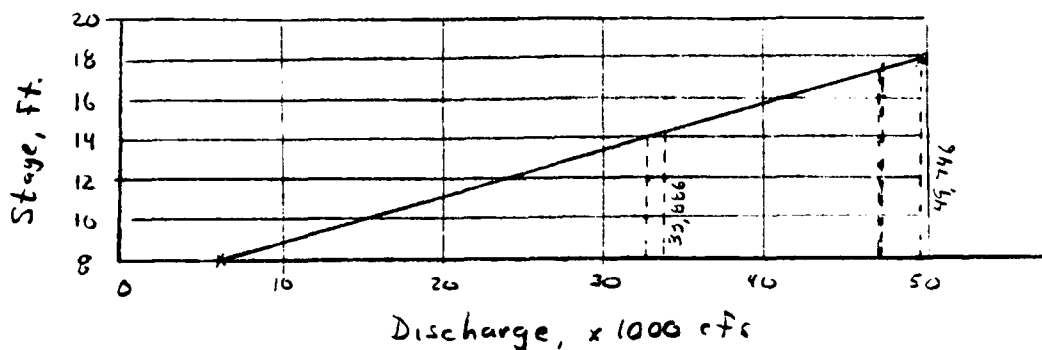
Sta. 24+00 below Norumbega Reservoir
 (1500 below Schencks Reservoir)

$$\text{channel slope} = \frac{10}{600} = .0167 \quad n = 0.08$$

$$V = F' R^{2/3} \quad F' = \frac{1.486}{.08} (.0167)^{1/2} = 2.40'$$

$$V = 2.40 R^{2/3}$$

D	W.P.	A	R ^{2/3}	F'	V	Q	Elev.
4	ft	sf			Fps	cfs	ft (MSL)
3	938	140.6	1.31	2.40	3.15	443	185
8	250	1000	2.53	2.40	6.08	6076	190
18	400	4250	4.87	"	11.69	49,697	200



① $Q_p = 49,746 \text{ cfs}$

② $Q_p = 33,870 \text{ cfs.}$

JOB NO. 79,206.1
DATE 12/7/79
BY EDD
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BOSTON MASSACHUSETTS

SHEET NO. D-12
JOB Dams
SUBJECT Narumbege Res.
CLIENT Corps

For ① $Q_{P_1} = 49,746 \text{ cfs}$ $d_1 = 18.0'$

$$Vol_1 = \frac{1960 + 4250}{2} \times \frac{600}{43,560} = 42.77 \text{ ac-ft}$$

$$Q_{P_2} = 49,746 \left(1 - \frac{42.77}{822}\right) = 47,158 \text{ cfs} \quad d_2 = 17.4'$$

$$Vol_2 = \frac{1960 + 3261}{2} \times \frac{600}{43,560} = 35.96 \text{ ac-ft}$$

$$Vol_{ave} = \frac{42.77 + 35.96}{2} = 39.37 \text{ ac-ft}$$

$$Q_{P_3} = 49,746 \left(1 - \frac{39.37}{822}\right) = 47,364 \text{ cfs} \quad d_3 = 17.5'$$

$$Vol_3 = \frac{1960 + 3719}{2} \times \frac{600}{43,560} = 39.11 \text{ ac-ft}$$

$$Q_{P_4} = 49,746 \left(1 - \frac{39.11}{822}\right) = 47,379 \text{ cfs} \quad d_4 = 17.55'$$

$$Vol_4 = \frac{1960 + 3743}{2} \times \frac{600}{43,560} = 39.27 \text{ ac-ft}$$

$$Vol_{ave} = \frac{39.11 + 39.27}{2} = 39.19 \text{ ac-ft}$$

$$Q_{P_5} = 49,746 \left(1 - \frac{39.19}{822}\right) = 47,374 \text{ cfs} \quad d_5 = 17.5'$$

$$Q_{out} = 47,374 \text{ cfs} \quad Elev. = 197.5 \pm'$$

For ②

$$Q_{P_1} = 33,870 \text{ cfs} \quad d_1 = 14.3'$$

$$Vol_1 = \frac{1520 + 2214}{2} \times \frac{600}{43,560} = 25.71 \text{ ac-ft}$$

$$Q_{P_2} = 33,870 \left(1 - \frac{25.71}{756}\right) = 32,718 \text{ cfs} \quad d_2 = 14.1'$$

$$Vol_2 = \frac{1520 + 2120}{2} \times \frac{600}{43,560} = 25.07 \text{ ac-ft}$$

$$Vol_{ave} = \frac{25.71 + 25.07}{2} = 25.39 \text{ ac-ft}$$

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SHEET NO. D-13
 JOB Dams
 SUBJECT Narumbege Res
 CLIENT Corps

$$Q_{p3} = 33,870 \left(1 - \frac{25.39}{756}\right) = 32,733 \text{ cfs} \quad d_3 = 14.0 \pm$$

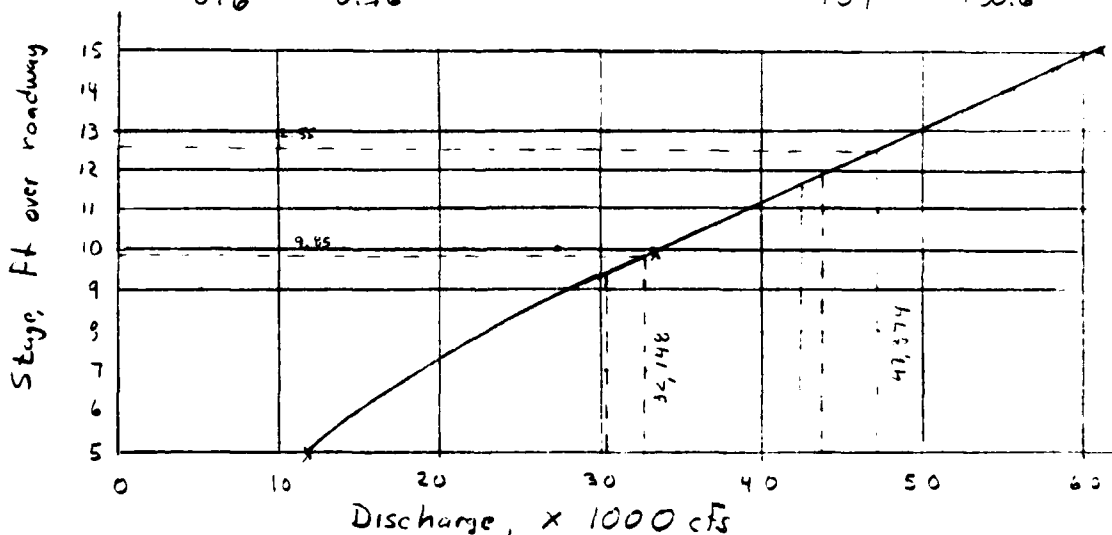
$$Q_{out} = \underline{32,733 \text{ cfs}} \quad \text{Elev.} = \underline{194.0 \pm}$$

Sta. 30+00 below Narumbege Reservoir
 (21+00 below Schenck's Reservoir)

Failure discharge overtops Mass Pike - assume any
 flow through culverts negligible (culverts blocked,
 carrying base flow, etc)

Have weir flow over roadway: $Q = CLH^{3/2}$
 $C = 2.63 \quad L = 400'$

$\frac{H}{\text{(over roadway)}}$	$H^{3/2}$	C	$\frac{L}{\text{ft}}$	$\frac{Q}{\text{cfs}}$	Elev (msl)	Area sq
5	11.18	2.63	400	11,762	135	563
10	31.62	"	"	33,267	140	7150
15	58.09	"	"	61,116	145	11338
0.6	0.46	"	"	489	190.6	



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SHEET NO 2-14
 JOB Dams
 SUBJECT Narumbege Res.
 CLIENT Corps

For ① $Q_{P_1} = 47,374 \text{ cfs}$ $d_1 = 12.55'$

$$Vol_1 = \frac{3730 + 9176}{2} \times \frac{600}{43,560} = 88.9' \text{ ac-ft}$$

$$Q_{P_2} = 47,374 \left(1 - \frac{88.9}{822}\right) = 42,250 \text{ cfs} \quad d_2 = 11.7'$$

$$Vol_2 = \frac{3730 + 8476}{2} \times \frac{600}{43,560} = 94.06$$

$$Vol_{ave} = \frac{88.9 + 94.06}{2} = 86.48$$

$$Q_{P_3} = 47,374 \left(1 - \frac{86.48}{822}\right) = 42,390 \text{ cfs} \quad d_3 = 11.9'$$

$$Vol_3 = \frac{3730 + 8638}{2} \times \frac{600}{43,560} = 85.18 \text{ ac-ft}$$

$$Q_{P_4} = 47,374 \left(1 - \frac{85.18}{822}\right) = 42,465 \text{ cfs} \quad d_4 = 12.0'$$

$$Vol_4 = \frac{3730 + 8720}{2} \times \frac{600}{43,560} = 85.74 \text{ ac-ft}$$

$$Vol_{ave} = \frac{85.18 + 85.74}{2} = 85.46 \text{ ac-ft}$$

$$Q_{P_5} = 47,374 \left(1 - \frac{85.46}{822}\right) = 42,449 \text{ cfs} \quad d_5 = 12.0'$$

$$Q_{out} = 42,449 \text{ cfs} \quad Elev = 192' \pm$$

For ② $Q_{P_1} = 32,733 \text{ cfs}$ $d_1 = 9.85'$

$$Vol_1 = \frac{2120 + 7039}{2} \times \frac{600}{43,560} = 63.07 \text{ ac-ft}$$

$$Q_{P_2} = 32,733 \left(1 - \frac{63.07}{756}\right) = 30,092 \text{ cfs} \quad d_2 = 9.4'$$

$$Vol_2 = \frac{2120 + 6706}{2} \times \frac{600}{43,560} = 60.79 \text{ ac-ft}$$

$$Vol_{ave} = \frac{63.07 + 60.79}{2} = 61.93 \text{ ac-ft}$$

$$Q_{P_3} = 32,733 \left(1 - \frac{61.93}{756}\right) = 30,052 \text{ cfs} \quad d_3 = 9.4'$$

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SHEET NO. 0-15
 JOB Dam
 SUBJECT Norumbega Res.
 CLIENT Corps

$$V_{c1} = \frac{2120 + 6743}{2} \times \frac{600}{43,560} = 61.03 \text{ ac-ft}$$

$$Q_{p4} = 32,733 \left(1 - \frac{61.03}{756}\right) = 30,091 \text{ cfs} \quad d_g = 9.48$$

$$V_{014} = \frac{2120 + 6765}{2} \times \frac{600}{43,560} = 61.19 \text{ ac-ft}$$

$$V_{\text{ave}} = \frac{61.19 + 61.03}{2} = 61.11 \text{ ac-ft}$$

$$Q_{p5} = 32,733 \left(1 - \frac{61.11}{756}\right) = 30,087 \text{ cfs} \quad d_s = 9.5' \pm$$

$$Q_{\text{out}} = \underline{30,100 \pm \text{cfs}} \quad \text{Elev.} = \underline{189.5' \pm}$$

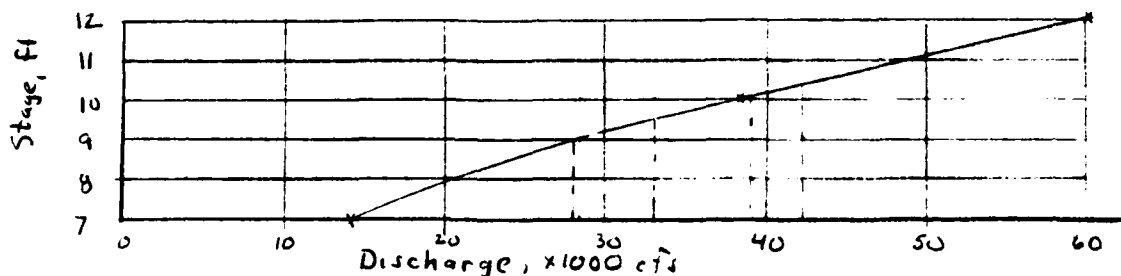
Sta. 35+00 below Norumbega Reservoir
 (26+00 below Schencks Reservoir)

$$\text{channel slope, } S = \frac{20}{500} = 0.040', \quad n = 0.06$$

$$V = f' R^{2/3} \quad f' = \frac{1.486}{0.06} (0.04)^{1/2} = 4.95$$

$$V = 4.95 R^{2/3}$$

D	WP	A	$R^{2/3}$	f'	V	Q	Elev.
ft	ft	sf			fps	cfs	(M.L.)
2	100	100	1.0	4.95	4.95	495	155
7	350	1225	2.31	4.95	11.46	14037	160
10	395	2342.5	3.30	"	16.31	38,216	163
12	425	3162.5	3.84	"	18.99	60,067	165



JOB NO. 79.206.1
DATE 12/1/79
BY FDD
CHK'D BY M.A.



HAYDEN, HARDING & BUCHANAN, INC.
CONSULTING ENGINEERS
BOSTON MASSACHUSETTS

SHEET NO. D-16
JOB Dams
SUBJECT Naticum Res.
CLIENT Corps

For ① $Q_p = 42,449 \text{ cfs}$ $d_1 = 10.4'$

$$Vol_1 = \frac{8680 + 2352}{2} \times \frac{500}{43,560} = 63.31 \text{ ac-ft}$$

$$Q_{p2} = 42,449 \left(1 - \frac{63.31}{922}\right) = 39,179 \text{ cfs} \quad d_2 = 10.1'$$

$$Vol_2 = \frac{8680 + 2382}{2} \times \frac{500}{43,560} = 63.49 \text{ ac-ft}$$

$$Vol_{ave} = \frac{63.31 + 63.49}{2} = 63.40 \text{ ac-ft}$$

$$Q_{p3} = 42,449 \left(1 - \frac{63.4}{922}\right) = 39,175 \text{ cfs} \quad d_3 = 10.1'$$

$$Q_{out} = 39,175 \text{ cfs} \quad Elev. = 163.1'$$

For ② $Q_p = 30,100 \text{ cfs}$ $d_1 = 9.5'$

$$Vol_1 = \frac{6790 + 2147}{2} \times \frac{500}{43,560} = 51.29 \text{ ac-ft}$$

$$Q_{p2} = 30,100 \left(1 - \frac{51.29}{756}\right) = 28,059 \text{ cfs} \quad d_2 = 9.0'$$

$$Vol_2 = \frac{6790 + 1955}{2} \times \frac{500}{43,560} = 50.19 \text{ ac-ft}$$

$$Vol_{ave} = \frac{51.29 + 50.19}{2} = 50.74 \text{ ac-ft}$$

$$Q_{p3} = 30,100 \left(1 - \frac{50.74}{756}\right) = 28,081 \text{ cfs} \quad d_3 = 9.0'$$

$$Q_{out} = 28,081 \text{ cfs} \quad Elev. = 162'$$

JOB NO. 79.206.1
 DATE 12/11/79
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 BOSTON MASSACHUSETTS

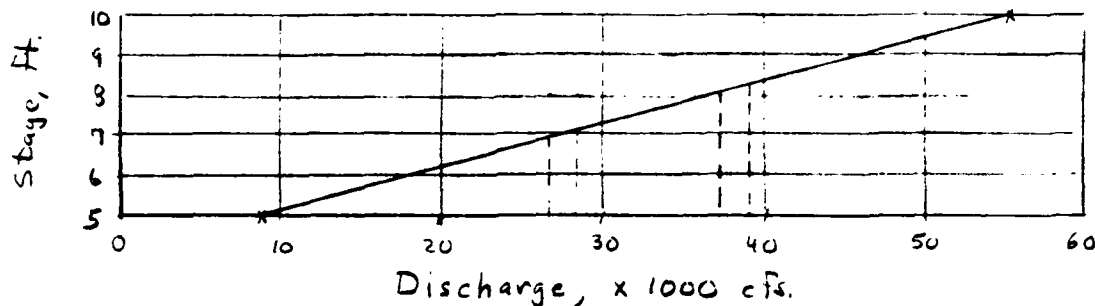
SHEET NO. 2-17
 JOB Dam
 SUBJECT Norumbega Res
 CLIENT Corps

Sta. 42+00 below Norumbega Reservoir
 (33+00 below Schencks Reservoir)

channel slope, $S = \frac{33}{700} = 0.047$ $n = 0.06$

$V = f' R^{2/3}$
 $V = 5.38 R^{2/3}$
 $f' = \frac{1.49}{0.06} (0.047)^{1/2} = 5.38$

D	WP	A	$R^{2/3}$	f'	V	Q	Elev
ft	ft	sf			fps	cfs	MSL)
1.7	119	101.2	0.90	5.38	4.82	448	121.7
10	700	3500	2.94	5.38	15.92	55,355	130
5	350	975	1.85	"	9.94	8,698	125



For ① $Q_{P1} = 39,175 \text{ cfs}$ $d_1 = 8.3'$

$Vol_1 = \frac{2370 + 2411}{2} \times \frac{700}{43,560} = 38.42 \text{ ac-ft}$

$Q_{P2} = 39,175 \left(1 - \frac{38.42}{822}\right) = 37,344 \text{ cfs}$ $d_2 = 9.1'$

$Vol_2 = \frac{2370 + 2296}{2} \times \frac{700}{43,560} = 37.49 \text{ ac-ft}$

$Vol_{ave} = \frac{38.42 + 37.49}{2} = 37.96$

$Q_{P3} = 39,175 \left(1 - \frac{37.96}{822}\right) = 37,366 \text{ cfs}$ $d_3 = 9.1'$

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 DATE 12/11/79
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 BOSTON MASSACHUSETTS

SHEET NO. D-18
 JOB Dams
 SUBJECT Norumbega Res.
 CLIENT Carpa

For ① $Q_{out} = 37,366 \text{ cfs}$ Elev = 129.1'

For ② $Q_p = 28,081 \text{ cfs}$ $d_1 = 7.1'$

$Vol_1 = \frac{2050 + 1764}{2} \times \frac{700}{43,560} = 30.65 \text{ ac-ft}$

$Q_{p2} = 28,081 \left(1 - \frac{30.65}{756}\right) = 26,943 \text{ cfs}$ $d_2 = 6.9'$

$Vol_2 = \frac{2050 + 1666}{2} \times \frac{700}{43,560} = 29.86 \text{ ac-ft}$

$Vol_{ave} = \frac{30.65 + 29.86}{2} = 30.26 \text{ ac-ft}$

$Q_{p3} = 28,081 \left(1 - \frac{30.26}{756}\right) = 26,957 \text{ cfs}$ $d_3 = 7.0 \pm'$

$Q_{out} = 26,957 \text{ cfs}$ Elev = 127' ±

Sta. 58+00 below Norumbega Reservoir
 (49+00 below Schenck's Reservoir)

channel slope, $S = \frac{15}{1600} = 0.00938'$ $n = 0.06$

$V = F' R^{2/3}$ $F' = \frac{1.486}{0.06} (0.00938)^{1/2} = 2.40$

$V = 2.40 R^{2/3}$

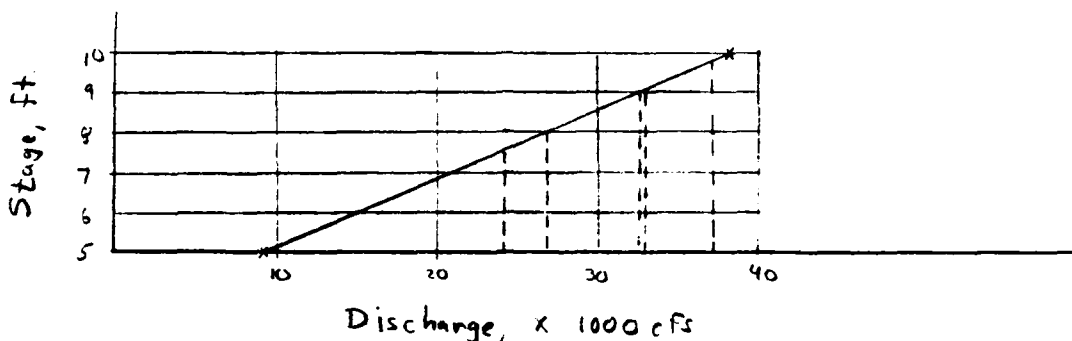
$\frac{D}{ft}$	$\frac{WP}{ft}$	$\frac{A}{sf}$	$\frac{R^{2/3}}$	$\frac{F'}{}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{\text{Elev.}}{MSL}$
5	450	1625	2.36	2.40	5.67	9219	110
10	550	4125	3.86	"	9.26	38,199	115
1	250	225	0.93	"	2.23	503	106

JOB NO. 79.206.1
 DATE 12/11/79
 BY FDD
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 BOSTON MASSACHUSETTS

SHEET NO. 2-19
 JOB Dams
 SUBJECT Narumbege Res.
 CLIENT Corpor



For ① $Q_{P_1} = 37,366 \text{ cfs}$ $d_1 = 9.8'$

$$Vol_1 = \frac{2350 + 4070}{2} \times \frac{1400}{43,560} = 103.2 \text{ ac-ft}$$

$$Q_{P_2} = 37,366 \left(1 - \frac{103.2}{822}\right) = 32,675 \text{ cfs} \quad d_2 = 9.0'$$

$$Vol_2 = \frac{2350 + 3585}{2} \times \frac{1400}{43,560} = 95.4 \text{ ac-ft}$$

$$Vol_{ave} = \frac{103.2 + 95.4}{2} = 99.3 \text{ ac-ft}$$

$$Q_{P_3} = 37,366 \left(1 - \frac{99.3}{822}\right) = 32,852 \text{ cfs} \quad d_3 = 9.1'$$

$$Vol_3 = \frac{2350 + 3638}{2} \times \frac{1400}{43,560} = 96.2 \text{ ac-ft}$$

$$Q_{P_4} = 37,366 \left(1 - \frac{96.2}{822}\right) = 32,992 \text{ cfs} \quad d_4 = 9.15'$$

$$Vol_4 = \frac{2350 + 3665}{2} \times \frac{1400}{43,560} = 96.7 \text{ ac-ft}$$

$$Vol_{ave} = \frac{96.2 + 96.7}{2} = 96.45 \text{ ac-ft}$$

$$Q_{P_5} = 37,366 \left(1 - \frac{96.45}{822}\right) = 32,982 \text{ cfs} \quad d_5 = 9.15'$$

$$Q_{out} = 32,982 \text{ cfs} \quad Elev. = 114.1 \text{ ft}$$

JOB NO. 79.206.1
 DATE 12/11/79
 BY FDD
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HAYDEN, HARDING & BUCHANAN, INC.
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 BOSTON MASSACHUSETTS

SHEET NO. D-20
 JOB Dam
 SUBJECT Narumbege Res.
 CLIENT Corps

For ② $Q_p = 26,957 \text{ cfs}$ $d_1 = 8.0'$

$$Vol_1 = \frac{1710 + 3065}{2} \times \frac{1400}{43560} = 76.7 \text{ ac-ft}$$

$$Q_{p2} = 26,957 \left(1 - \frac{76.7}{756}\right) = 24,221 \text{ cfs} \quad d_2 = 7.6'$$

$$Vol_2 = \frac{1710 + 2863}{2} \times \frac{1400}{43560} = 73.5 \text{ ac-ft}$$

$$Vol_{ave} = \frac{76.7 + 73.5}{2} = 75.1 \text{ ac-ft}$$

$$\checkmark Q_{p3} = 26,957 \left(1 - \frac{75.1}{756}\right) = 24,279 \text{ cfs} \quad d_3 = 7.65'$$

$$Vol_3 = \frac{1710 + 2998}{2} \times \frac{1400}{43560} = 73.9 \text{ ac-ft}$$

$$Q_{p4} = 26,957 \left(1 - \frac{73.9}{756}\right) = 24,322 \text{ cfs} \quad d_4 = 7.7'$$

$$Vol_4 = \frac{1710 + 2913}{2} \times \frac{1400}{43560} = 74.3 \text{ ac-ft}$$

$$Vol_{ave} = \frac{73.9 + 74.3}{2} = 74.1$$

$$Q_{p5} = 26,957 \left(1 - \frac{74.1}{756}\right) = 24,315 \text{ cfs} \quad d_5 = 7.7'$$

$$Q_{out} = \underline{24,315} \quad Ele. = \underline{112.7' \pm}$$

Note: Generally speaking, difference in elevation between Failure conditions ① and ② are on the order of 1-2'. Thus impact areas for both conditions would be approximately the same.

JOB NO. 792061
 DATE 1-11-80
 BY MA
 CH'D BY EDD



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JOB Dams SHEET NO. 221
 SUBJECT Norumbega
 CLIENT COE

<u>Sta</u>	<u>Elev</u>	<u>Base Fld El</u>	<u>Ferrl, Fld Elev</u>	
0+00 Norumbega	251	252	- 275±	Dam Failure
14+00	230	231 Oak Str 1' Schaucks 1'	237	Oak Str 7'± Schaucks 9'±
18+00	200	201 6 homes 1±	207	8 homes 2'± 6 " 6'± -
24+00	182	185 2 homes 2'±	194	2 homes 10'± -
30+00	180	181 —	190	—
35+00 Pike	153	155 Pike 2'±	162	Pike 4'±
42+00	120	122 3 homes 2'±	127	3 homes 5'± 3 " 3'±
58+00	105	106 2 homes 1'±	113	9 homes 2'± 2 " 7'± - South Ave 2'±

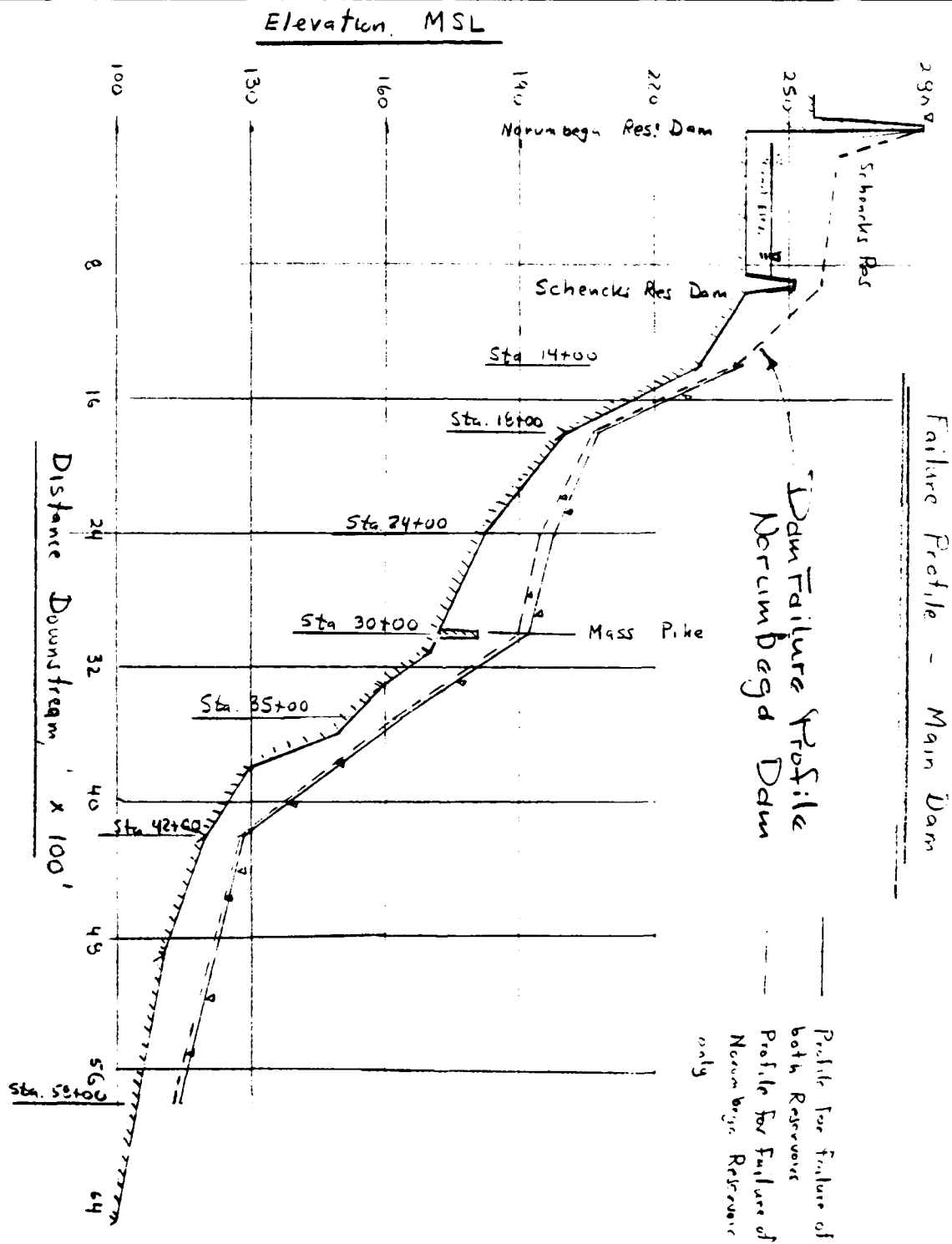
JOB NO. 79 206.1
 DATE 12/16/73
 BY EAD
 CH'D BY MB



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 BOSTON MASSACHUSETTS

SHEET NO. 2-22

JOB Dams
 SUBJECT Narum-bega Res.
 CLIENT Scarp



JOB NO 79.206.1
DATE 1/16/90
BY FDD
CHKD BY WLB



HAYDEN, HARDING & BUCHANAN, INC
CONSULTING ENGINEERS
BOSTON — WEST HARTFORD

SHEET NO 222a
JOB Dams
SUBJECT Yarimaega Res
CLIENT Corps

Check — Base Flow Flooding Conditions

Sta. 14+00 — See pg. 7 for calc's.

$$Q = 500 \text{ cfs} \quad \text{depth flooding} = 0.7' \pm \\ \text{Elev} = 231 \pm$$

Sta. 18+00 — See pg. 9 for calc's.

$$Q = 500 \text{ cfs} \quad \text{depth flooding} = 0.5' \pm \\ \text{Elev} = 201 \pm$$

Sta. 24+00 — See pg. 11 for calc's.

$$Q = 500 \text{ cfs} \quad \text{depth flooding} = 3' \pm \\ \text{Elev} = 185 \pm$$

Sta. 30+00 — See pg. 13 for calc's.

$$Q = 500 \text{ cfs} \quad \text{depth flooding} = 0.6' \pm \\ \text{Elev} = 191 \pm$$

Sta. 35+00 — See pg. 15 for calc's.

$$Q = 500 \text{ cfs} \quad \text{depth flooding} = 2' \pm \\ \text{Elev} = 155 \pm$$

JOB NO. 79 206.1
DATE 11/6/90
BY FDD
CHK'D BY MA



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SHEET NO. 2-22b
JOB Dams
SUBJECT Norimberga Res.
CLIENT Corpe

Base Flow Flooding Conditions

Sta. 42+00 - See pg. 17 for calc's

$Q = 500 \text{ cfs}$ depth flooding = $1.7' \pm$
Elev. = $122' \pm$

Sta. 58+00 - See pg. 18 for calc's

$Q = 500 \text{ cfs}$ depth flooding = $1'$
Elev. = $106' \pm$

Summarizing Base Flow Flooding

For $Q = 500 \text{ cfs}$, get $1-3' \pm$ flood depths

Have $10 \pm$ houses which will be flooded by
 $1-2'$ of water

Mass Pike overtopped by $0.6'$

several improved roads flooded
by $1-3'$

JOB NO. 79.206.1
 DATE 2/7/79
 BY FDD
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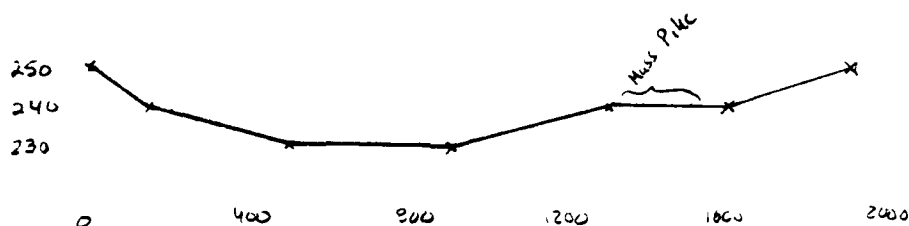
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SHEET NO. 2-23

JOB Dams
 SUBJECT Narumbaga Res
 CLIENT Corps

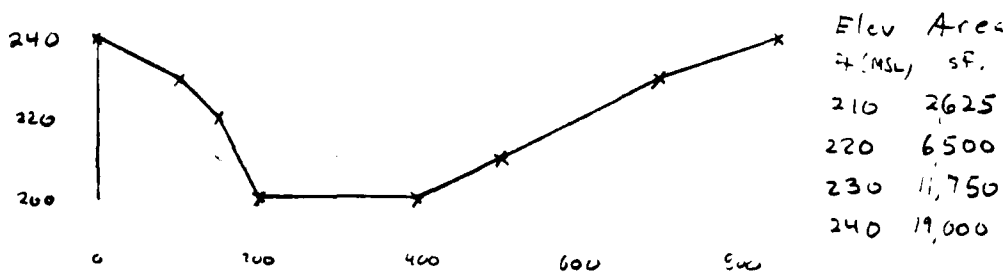
Cross Sections - Failure of Main Dam

Cross Sections looking upstream



Elev.	Area
ft (MSL)	sf
240	7,750
250	24,500

Sta. 14+00 below Narumbaga Reservoir
 (along Oak St)



Elev	Area
ft (MSL)	sf.
210	2,625
220	6,500
230	11,750
240	19,000

Sta. 18+00 below Narumbaga Reservoir

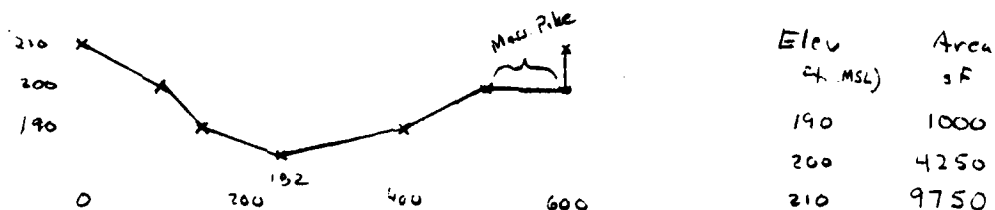
JOB NO 79.206.1
 DATE 2/2/79
 BY FDD
 CH'D BY HT



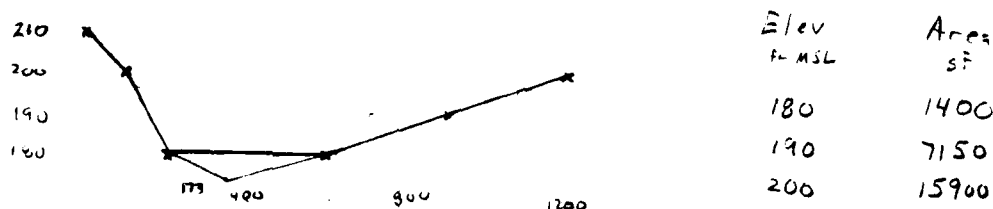
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SHEET NO 2-24
 JOB Dams
 SUBJECT Norumbega Res
 CLIENT Corps

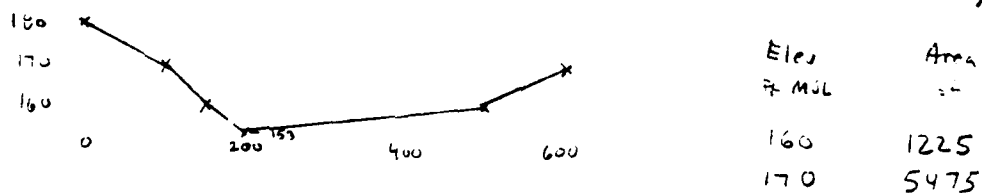
Cross sections - Failure of Main Dam Cross Sections looking Upstream



Sta. 24+00 below Norumbega Reservoir



Sta. 30+00 below Norumbega Reservoir (Mass Pike -
 assume culverts blocked)



Sta. 35+00 below Norumbega Reservoir



Sta. 42+00 below Norumbega Reservoir

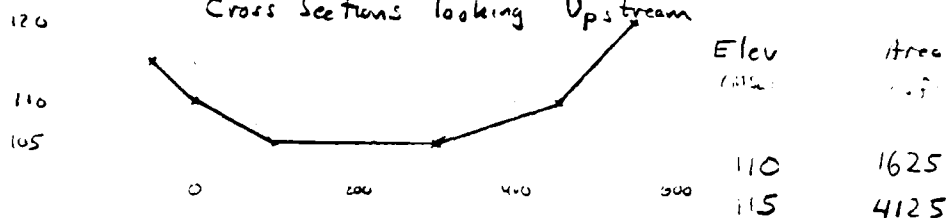
JOB NO. 79-206.1
 DATE 12/11/79
 BY EDD
 CH'D BY AMX



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 BOSTON MASSACHUSETTS

SHEET NO. D-25
 JOB Dam
 SUBJECT Norumbega Res
 CLIENT Corps

Cross Sections - Failure of Main Dam
 Cross Sections looking Upstream



Sta. 58+00 below Norumbega Reservoir

JOB NO 7-206.1
 DATE 12/5/79
 BY FDD
 CHD BY WJ

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 BOSTON — WEST HARTFORD

SHEET NO. 2-26
 JOB Dams
 SUBJECT Narumoga Res
 CLIENT Corps

(II) a : Failure of South Dike (Glen Rd.)
Sta 1+50 [Dike #4]

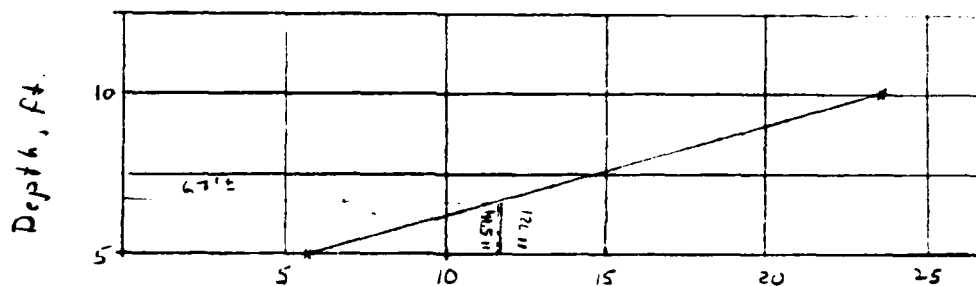
channel slope: $\frac{10'}{800'} = .0125'$ $n = 0.09$ (heavy brush, some trees)

$V = \frac{1.486}{n} R^{2/3} S^{1/2} = F' R^{2/3}$ $F' = \frac{1.486}{0.09} (.0125)^{1/2} = 2.09$

$V = (2.09) R^{2/3}$

Reservoir Volume = $V_0 = V_{12M} = 500$ ac-ft

$\frac{D}{4}$	$\frac{WP}{4}$	$\frac{A}{sf}$	$\frac{R^{2/3}}{}$	$\frac{F'}{}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	Elev
10	500	3250	3.48	2.09	7.24	23,530	270
5	300	1125	2.42	"	5.04	5673	265



[See page 5]

Discharge, x 1000 cfs.

$Q_{P_1} = 7,814$ cfs $d_1 = 5.6'$

$Vol_1 = \frac{1800 + 1386}{2} \times \frac{150}{43,560} = 5.49$ ac-ft $< 1/2 \times 500$ ac-ft

$Q_{P_2} = 7,814 \left(1 - \frac{5.49}{500}\right) = 7,728$ cfs $d_2 = 5.5'$

$Vol_2 = \frac{1900 + 1354}{2} \times \frac{150}{43,560} = 5.43$ $Vol_{tot} = \frac{5.49 + 5.43}{2} =$

$Q_{P_3} = 7,814 \left(1 - \frac{5.46}{500}\right) = 7,729$ cfs

Elev = 265.5 ± $Q_{out} = 7,729$ cfs

JOB NO. 79.206.1
 DATE 12/5/79
 BY FDD
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SHEET NO. 2-27

JOB Dams
 SUBJECT Harrington Res
 CLIENT Corps

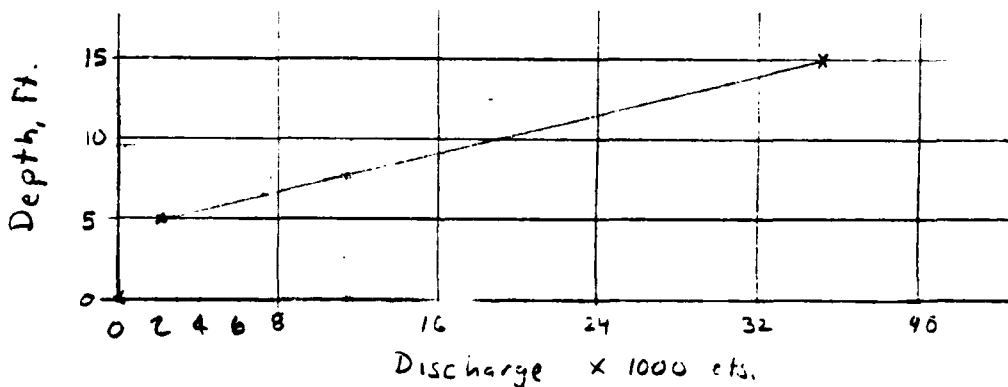
Sta. 5+00

channel slope = 0.0125', $n = 0.08$

$$V = F' R^{2/3} \quad F' = 2.08$$

$$V = 2.08 R^{2/3}$$

$\frac{D}{ft}$	$\frac{WP}{ft}$	$\frac{A}{sq\ ft}$	$\frac{R^{2/3}}{ft}$	$\frac{F'}{ft}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{Elev}{ft}$
5	300	625	1.64	2.08	3.40	2126	260
15	500	4125	4.11	"	8.55	35,274	270



$$Q_{P_1} = 7,729 \text{ cfs.} \quad d_1 = 6.5'$$

$$Vol_1 = \frac{1370 + 1023}{2} \times \frac{350}{43,560} = 9.61 \text{ cu-ft}$$

$$Q_{P_2} = 7729 \left(1 - \frac{9.61}{500}\right) = 7580 \text{ cfs.} \quad d_2 = 6.4'$$

$$Vol_2 = \frac{1370 + 995}{2} \times \frac{350}{43,560} = 9.50 \text{ cu-ft}$$

$$Vol_{ave} = \frac{9.61 + 9.50}{2} = 9.56 \text{ cu-ft}$$

JOB NO. 79.206.1
 DATE 12/6/79
 BY FDD
 CH'D BY VW

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SHEET NO. 228
 JOB Dams
 SUBJECT Nor. m. b. g. Res.
 CLIENT Corp.

$$Q_{P2} = 7729 \left(1 - \frac{9.56}{500}\right) = 7581 \text{ cfs}$$

$$\text{Elev} = 264.4 \pm \quad C_{out} = 7581 \text{ cfs}$$

Sta 8+00

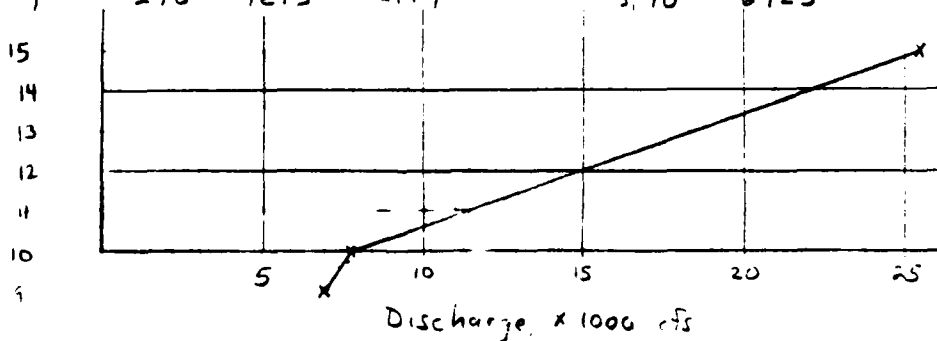
channel slope = 0.0125', $n = 0.09$

$$V = F' R^{2/3} \quad F' = 2.08$$

$$V = 2.08 R^{2/3}$$

$\frac{D}{ft}$	$\frac{W.P.}{ft}$	$\frac{A}{sf}$	$\frac{R^{2/3}}{ft}$	$\frac{F'}{ft}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{\text{Elev}}{ft}$
10	300	1350	2.74	2.08	5.70	7692	260
20	500	5350	4.89	"	10.18	54,463	270
15	400	3100	3.94	"	8.20	25,425	265
9	270	1215	2.74	"	5.70	6923	

Stage, Ft.



$$Q_1 = 7581 \text{ cfs} \quad d_1 = 9.8'$$

$$Vol_1 = \frac{1010 + 1596}{2} \times \frac{300}{43.560} = 9.97 \text{ ac-ft}$$

$$Q_{P2} = 7581 \left(1 - \frac{8.97}{500}\right) = 7445 \text{ cfs} \quad d_2 = 9.6'$$

$$Vol_2 = \frac{1010 + 1596}{2} \times \frac{300}{43.560} = 8.76 \text{ ac-ft}$$

$$Vol_{ave} = \frac{8.97 + 8.76}{2} = 8.87 \text{ ac-ft}$$

JOB NO. 79.206.1
 DATE 12/6/79
 BY FD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
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 BOSTON — WEST HARTFORD

SHEET NO. 2-29
 JOB Dams
 SUBJECT Narumboga Res
 CLIENT Corps

$$Q_{P_3} = 7581 \cdot \left(1 - \frac{0.87}{500}\right) = 7447 \text{ cfs. } d_3 = 9.6'$$

$$\text{Elev} = 260.6 \pm \quad Q_{out} = 7447 \text{ cfs}$$

Sta 17+00

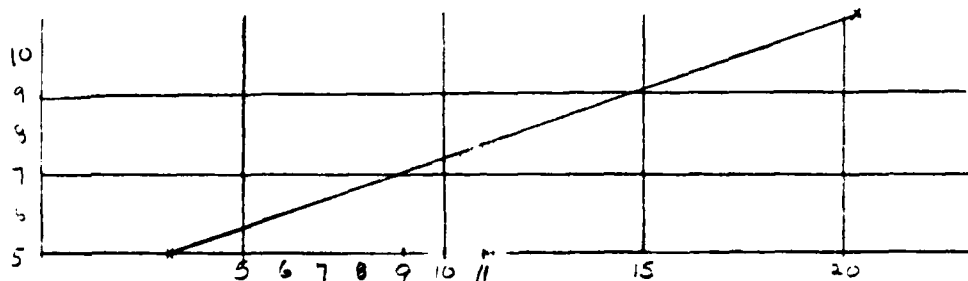
$$\text{channel slope} = \frac{40}{800} = 0.05 \checkmark$$

$$n = 0.06 \quad (\text{developed area, some trees})$$

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \quad F' = \frac{1.486}{0.06} (0.05)^{1/2} = 5.53 \checkmark$$

$$V = F' R^{2/3} = 5.53 R^{2/3}$$

$\frac{D}{ft}$	$\frac{WP}{ft}$	$\frac{A}{sf}$	$\frac{R^{2/3}}$	$\frac{F'}{}$	$\frac{V}{fps}$	$\frac{Q}{cfs}$	$\frac{\text{Elev.}}{}$
10	250	1250	2.94	5.53	16.26	20,321	220
5	125	313	1.85	"	10.22	3193	215



$$Q_P = 7,447 \text{ cfs } d_1 = 6.5'$$

$$\text{Vol.}_1 = \frac{1560 + 5248}{2} \times \frac{900}{43,560} = 21.57 \text{ ac-ft}$$

$$Q_{P_2} = 7447 \left(1 - \frac{1}{500}\right) = 7126 \checkmark \text{ cfs } d_2 = 6.4'$$

$$\text{Vol.}_2 = \frac{1560 + 512}{2} \times \frac{900}{43,560} = 21.40 \text{ ac-ft.}$$

JOB NO. 79.206.1
 DATE 12/6/79
 BY FDD
 CND BY MM

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 BOSTON — WEST HARTFORD

SHEET NO. D-30
 JOB Dams
 SUBJECT Norumbega Res
 CLIENT Corps

$$V_{\text{ave}} = \frac{21.57 + 21.40}{2} = 21.49 \text{ cfs}$$

$$Q_{p_3} = 7447 \left(1 - \frac{21.49}{500}\right) = 7127 \text{ cfs} \quad d_3 = 6.4'$$

$$\text{Elev.} = 216.4 \pm \quad Q_{\text{out}} = 7127 \text{ cfs}$$

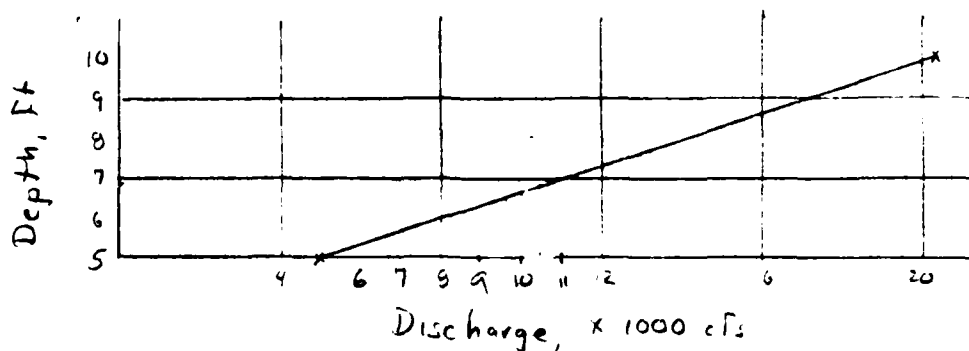
Sta 32+00

$$\text{channel slope} = \frac{10}{900} = .0111' \quad n = 0.06$$

$$V = F' R^{2/3} \quad F' = \frac{1.486}{.06} \times (.0111)^{1/2} = 2.60$$

$$V = 2.60 R^{2/3}$$

<u>D</u>	<u>W.P.</u>	<u>A</u>	<u>R^{2/3}</u>	<u>F'</u>	<u>V</u>	<u>Q</u>	<u>Elev.</u>
5	225	813	2.36	2.60	6.15	4999	195
10	350	2250	3.48	"	9.05	20,351	200



$$Q_p = 7127 \text{ cfs} \quad d_1 = 5.7'$$

JOB NO. 79.206.1
 DATE 12/6/79
 BY FDD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

SHEET NO. 31

JOB Dams
 SUBJECT Norumbega Res.
 CLIENT Corporation

$$Q_{P_1} = 7,127 \quad d_1 = 5.7' \quad \checkmark$$

$$Vol_1 = \frac{520+976}{2} \times \frac{1500}{43,560} = 25.76 \text{ ac-ft} \quad \checkmark$$

$$Q_{P_2} = 7,127 \left(1 - \frac{25.76}{500}\right) = 6760 \text{ cfs} \quad d_2 = 5.6' \quad \checkmark$$

$$Vol_2 = \frac{520+952}{2} \times \frac{1500}{43,560} = 25.34 \text{ ac-ft}$$

$$Vol_{ave} = \frac{25.76 + 25.34}{2} = 25.55$$

$$Q_{P_3} = 7,127 \left(1 - \frac{25.55}{500}\right) = 6763 \text{ cfs} \quad d_3 = 5.6' \quad \checkmark$$

$$Elev = 195.6 \pm \quad Q_{out} = 6,763 \text{ cfs}$$

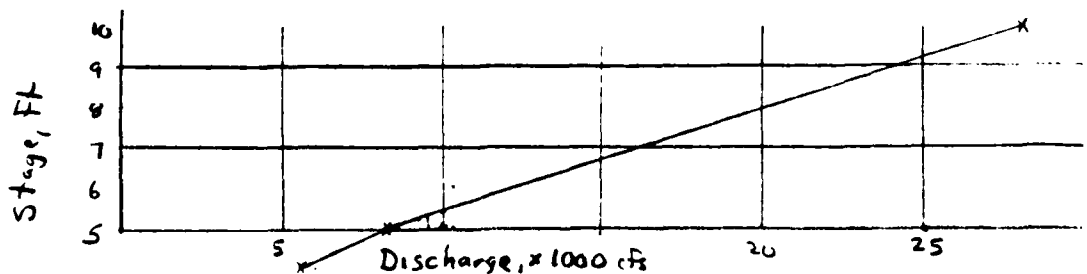
Sta. 38+00 - just upstream of bridge

Channel Slope - Flat say $\frac{3}{600} = 0.005' \quad n=0.06 \quad \checkmark$

$$V = F' R^{2/3} \quad F' = \frac{1.486}{0.06} (0.005)^{1/2} = 1.75 \quad \checkmark$$

$$V = 1.75 R^{2/3}$$

D	WP	A	$R^{2/3}$	F'	V	Q	Elev
5	400	1750	2.69	1.75	4.71	9238	195
4	380	1360	2.35	"	4.11	5592	194
10	500	4000	4.00	"	7.0	28,000	200



JOB NO. 79,206.1
 DATE 12/6/79
 BY FDD
 CH'D BY WJ



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

SHEET NO. 2-32
 JOB Dams
 SUBJECT Norimba Res.
 CLIENT Corps

$$Q_p = 6,763 \text{ cfs} \quad d_1 = 4.4'$$

$$Vol_1 = \frac{960.1514}{2} \times \frac{600}{43,560} = 17.04 \text{ ac-ft}$$

$$Q_{p2} = 6,763 \left(1 - \frac{17.04}{500}\right) = 6,533 \text{ cfs} \quad d_2 = 4.3'$$

$$Vol_2 = \frac{960 + 1475}{2} \times \frac{600}{43,560} = 16.77 \text{ ac-ft}$$

$$Vol_{ave} = \frac{17.04 + 16.77}{2} = 16.91$$

$$Q_{p3} = 6,763 \left(1 - \frac{16.91}{500}\right) = 6,534 \text{ cfs} \quad d_3 = 4.3'$$

$$Elev. = 194.3 \pm \quad Q_{out} = 6,534 \text{ cfs.}$$

Sta 38+50 - Wellesley St. Embankment

Assume any culvert through Embankment
 blocked (by debris, base flow etc.)

Will have weir flow over embankment
 Assume broad crested weir with $C = 2.63$ ($L = 600'$)

$$Q = CL H^{3/2}$$

H	$H^{3/2}$	CL	Q
ft			cfs
1.0	1.0	1578	1578
2.0	2.83	"	4463
3.0	5.20	"	8200
2.6	4.19	"	6616

Roadway overtopped by $2.6' \pm$, $Q = 6534 \text{ cfs}$
 \therefore elevation = $192.6' \pm$

JOB NO. 792061
 DATE 1-11-80
 BY MA
 CND BY _____



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

2-33

SHEET NO. _____
 JOB Dams
 SUBJECT Norumbega
 CLIENT COE

Dam Failure - DiKe # 4

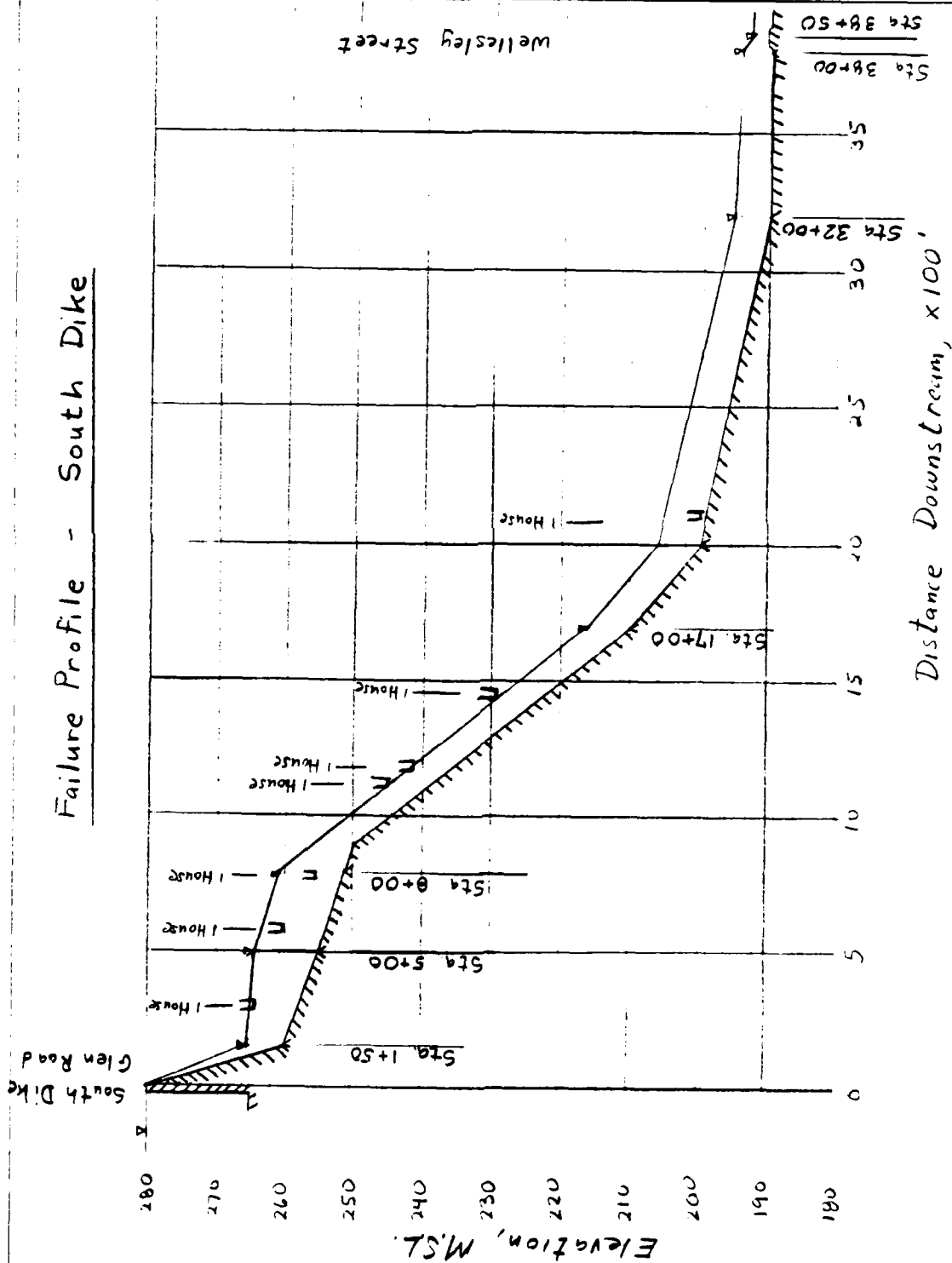
<u>Sta</u>	<u>Elev</u>	<u>Dam Failure Elev.</u>	<u>Damage</u>
1+50	260	266	6' Road
5+00	255	265	10' 2 houses 5'
8+00	251	261	10' 1 house 2'
17+00	210	216	6' 2 houses 6' 3 houses 2'
32+00	190	196	6' 13 houses 6' 10 " 2'
38+00	190	194	4' 10 houses 4'
38+50	190	193	3' 2 houses 3'

JOB NO. 79.206.1
 DATE 12/10/79
 BY FDD
 CHD BY _____



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

SHEET NO. 2-34
 JOB Dams
 SUBJECT Vermont Res
 CLIENT Corps



JOB NO 79.206.1
 DATE 12/5/79
 BY FDD
 CH'D BY MA

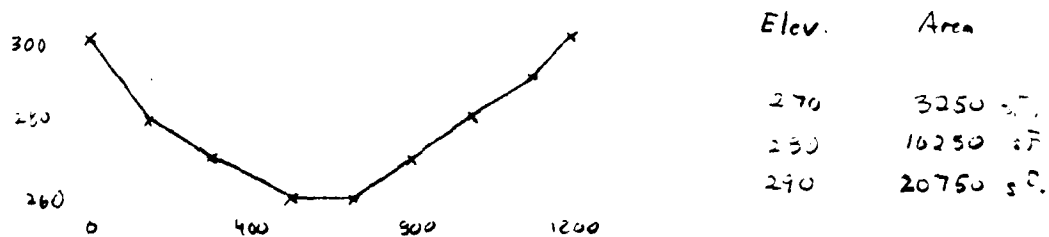


HAYDEN, HARDING & BUCHANAN, INC
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

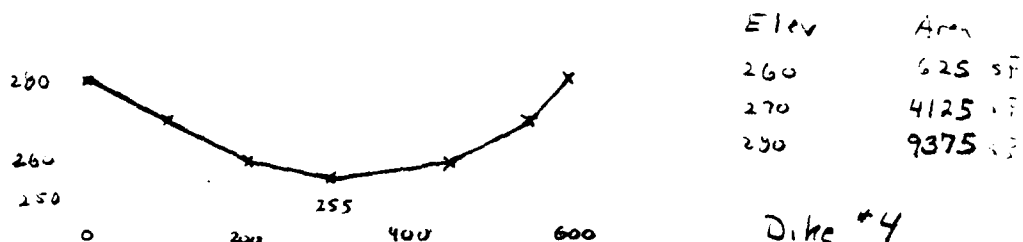
SHEET NO 235
 JOB Dams
 SUBJECT Narumbege
 CLIENT Corps

Cross Sections - South Dike - Glen Road Area

Sections Looking Downstream

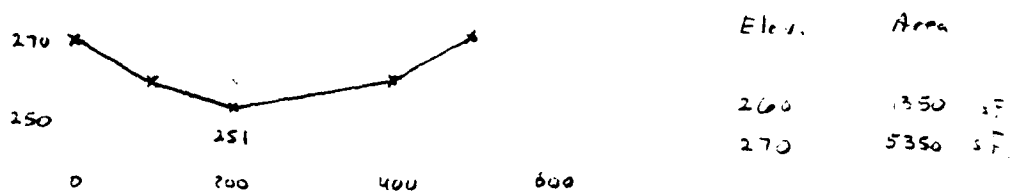


Sta. 1+50 below South Dike

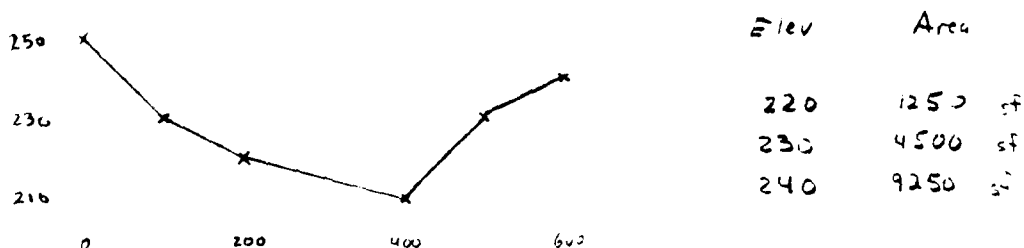


Dike #4

Sta. 5+00 below South Dike



Sta. 9+00 below South Dike



Sta. 17+00 below South Dike

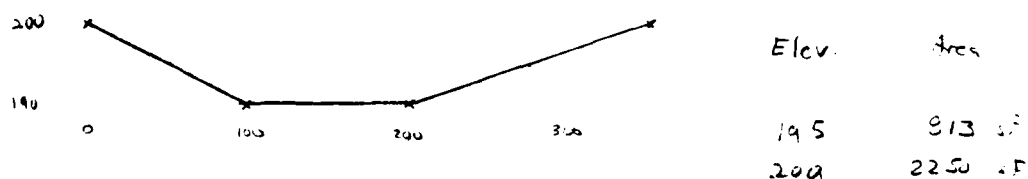
JOB NO. 79.206.1
 DATE 11/5/79
 BY FOO
 CH'D BY WA

HH & B HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON — WEST HARTFORD

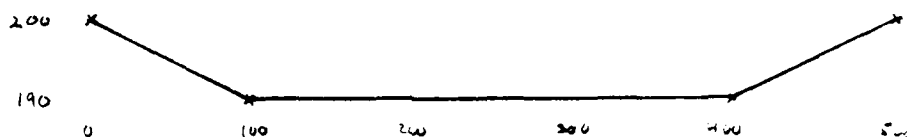
SHEET NO. 2-31
 JOB Dams
 SUBJECT Natunkeag
 CLIENT CCE

Cross Sections - South Dike - Glen Road Area

Sections Looking Downstream

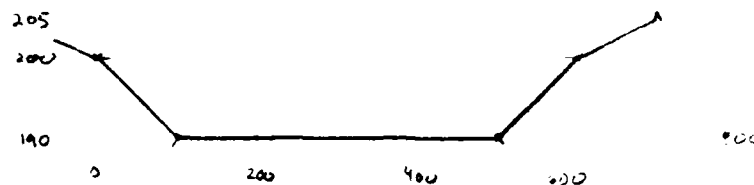


Sta 32+00 below South Dike



Sta 38+00 below South Dike

Elev.	Area
195	1750
200	4000



Sta 38+50 below South Dike - Wellesley St.
 (Assume culvert blocked)

JOB NO. 79.206.1
 DATE 12/10/79
 BY FDD
 CH'D BY MLA

HH & B HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. 2-37
 JOB Dams
 SUBJECT Yamacoma Res.
 CLIENT Corporation

↓ **Dikes 2-3**
 (II) b. Failure of "West Dike" [See Page 5]
 along Rte 90 "

$$Q_F = 7814 \text{ cfs.}$$

$$Vol @ L_{a.1} = Vol.$$

$$Vol_P = 500 \text{ ac-ft.}$$

Sta. 2+00

$$n = 0.08 \text{ (heavy brush)}$$

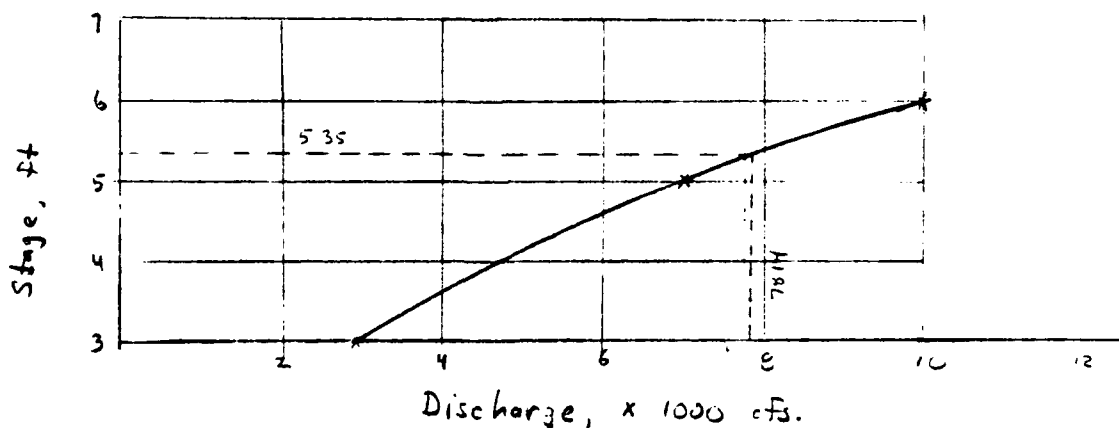
$$S = 0.057$$

$$V = F' R^{2/3}$$

$$V = 4.43 R^{2/3}$$

$$F' = \frac{1.486}{0.08} (0.057)^{1/2} = 4.43'$$

D ft	WP ft	A sf	$R^{2/3}$	F'	V fps	Q cfs	Elev. MSL
10	200	1500	3.86	4.43	17.09	25,632	270
5	150	625	2.60	"	11.53 ✓	7,203 ✓	265
7	160	780	2.89	"	12.60	9937	266
3	130	345	1.92	"	8.52	2939	263



$$Q_P = 7814 \text{ cfs.} \quad d_1 = 5.35'$$

$$Vol_1 = \frac{1200 + 675}{2} \times \frac{200}{43.560} = 4.312 \text{ ac-ft.}$$

JOB NO. 79-296.1
 DATE 12/10/79
 BY END
 CH'D BY WPA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. 2-30

JOB Dams
 SUBJECT Norwega Res.
 CLIENT Copa

$$Q_{P2} = 7814 \left(1 - \frac{4.312}{500}\right) = 7747 \checkmark \text{ cfs} \quad d_2 = 530'$$

$$Vol_2 = \frac{1200 + 670}{2} \times \frac{200}{43.360} = 4.294 \text{ ac-ft}$$

$$Vol_{ave} = \frac{4.312 + 4.294}{2} = 4.303 \text{ ac-ft}$$

$$Q_{P3} = 7814 \left(1 - \frac{4.303}{500}\right) = 7747 \text{ cfs}$$

$$Q_{out} = 7747 \text{ cfs} \quad Elev. = 265.3'$$

Sta. 8+00

$$n = 0.08$$

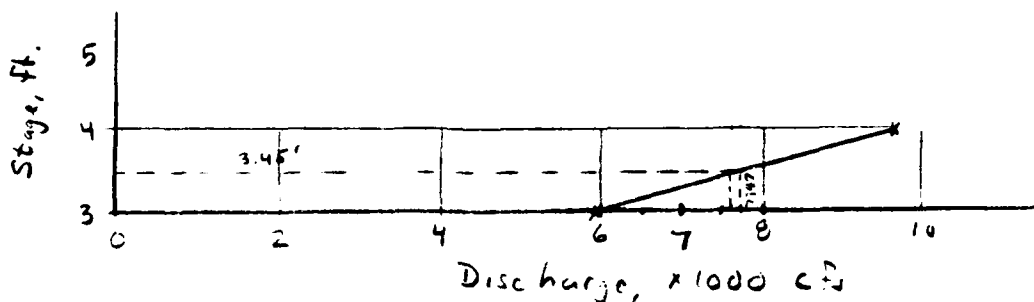
$$S = 0.0296$$

$$V = F' R^{2/3}$$

$$F' = \frac{1.486}{2.00} (.0296)^{1/2} = 3.14 \checkmark$$

$$V = \frac{F' R^{2/3}}{R^{2/3}}$$

D ft.	WP ft.	A sq	R ^{2/3}	F'	V ft/s	Q cfs	Elev MSL
5	350	1625	2.80	3.14	9.79	14,279	245
3	315	923	2.05 ✓	"	6.45 ✓	5954 ✓	243
4	320	1240	2.49	"	7.79	9649	244



$$Q_P = 7747 \text{ cfs} \quad d_1 = 3.45'$$

JOB NO. 79 206.1
 DATE 12/10/79
 BY EOD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. 8-39
 JOB Dam
 SUBJECT Newbury Res
 CLIENT Corp

$$Q_{P_1} = 7,747 \text{ cfs. } d_1 = 3.45'$$

$$Vol_1 = \frac{674 + 1065}{2} \times \frac{600}{43,560} = 11.97 \text{ ac-ft } \checkmark$$

$$Q_{P_2} = 7747 \left(1 - \frac{11.97}{500}\right) = 7,562' \text{ cfs. } d_2 = 3.35'$$

$$Vol_2 = \frac{674 + 1033}{2} \times \frac{600}{43,560} = 11.76 \quad Vol_{ave} = \frac{11.97 + 11.76}{2} = 11.87$$

$$Q_{P_2} = 7747 \left(1 - \frac{11.87}{500}\right) = 7,563 \text{ cfs.}$$

$$Q_{out} = 7,563' \text{ cfs. } Elev. = 243.4'$$

Sta. 12+00

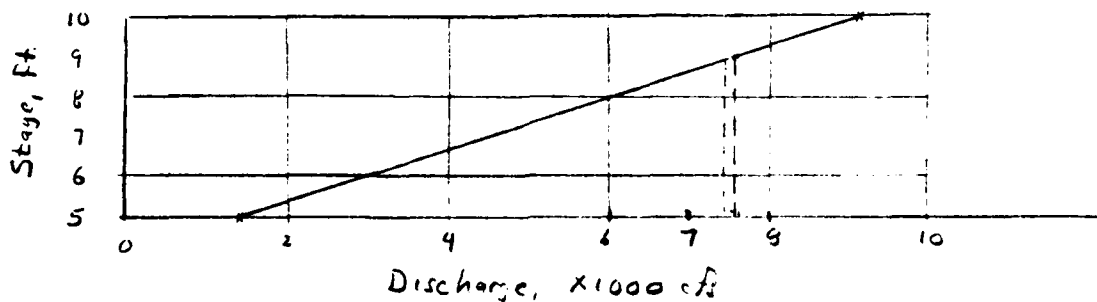
$$n = 0.08$$

$$S = 0.050$$

$$F' = \frac{1.486}{0.05} \cdot (0.05)^{1/2} = 4.15 \checkmark$$

$$V = F' R^{2/3} = 4.15 R^{2/3}$$

D	WP	A	R ^{2/3}	F'	V	Q	Elev.
ft	ft	sf			fps	cfs	(MSL)
10	150	750	2.94 ✓	4.15	12.20 ✓	9150 ✓	230
5	75	187.5	1.85	"	7.67	1438	225



$$Q_P = 7,563 \text{ cfs. } d_1 = 9.0' \checkmark$$

JOB NO. 79.206.1
 DATE 12/10/79
 BY PDD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON, MASSACHUSETTS

SHEET NO. 040
 JOB Dam
 SUBJECT Norumbega
 CLIENT Crops

$$Q_{P_1} = 7,563 \text{ cfs} \quad d_1 = 9.0'$$

$$Vol_1 = \frac{1050 + 608}{2} \times \frac{400}{43,560} = 7.61 \text{ ac-ft}$$

$$Q_{P_2} = 7,563 \left(1 - \frac{7.61}{500}\right) = 7,448 \text{ cfs} \quad d_2 = 9.9'$$

$$Vol_2 = \frac{1050 + 592}{2} \times \frac{400}{43,560} = 7.54 \text{ ac-ft}$$

$$Vol_{ave} = \frac{7.54 + 7.61}{2} = 7.58 \text{ ac-ft}$$

$$Q_{P_2} = 7,563 \left(1 - \frac{7.58}{500}\right) = 7,448 \text{ cfs}$$

$$Q_{out} = 7,448 \text{ cfs} \quad Elev = 228.9 \pm'$$

Sta 16+00

$$n = 0.08$$

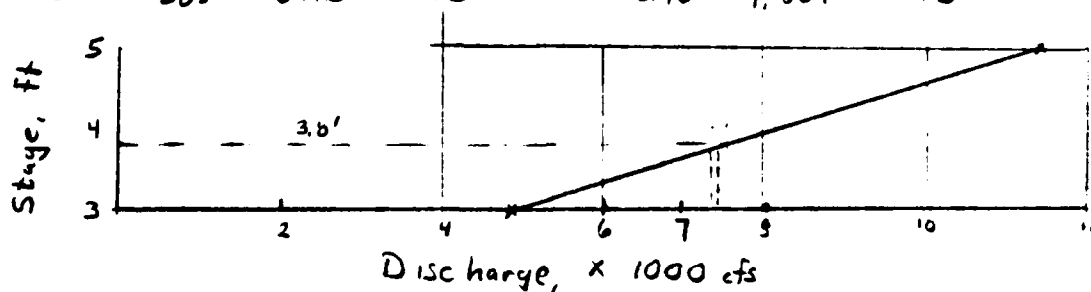
$$S = 0.025$$

$$F' = \frac{1.486}{0.08} \times (0.025)^{2/3} = 2.94$$

$$V = F' R^{2/3}$$

$$V = 2.94 R^{2/3}$$

<u>D</u>	<u>WP</u>	<u>A</u>	<u>R^{2/3}</u>	<u>F'</u>	<u>V</u>	<u>Q</u>	<u>Elev.</u>
10	400	3250	4.07	2.94	11.97	38,986	220
5	325	1437.5	2.71	"	7.96	11,444	215
3	285	817.5	2.03	"	5.96	4,869	213



JOB NO. 71,206.1
 DATE 12/10/71
 BY FDD
 CH'D BY MA



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON, MASSACHUSETTS

SHEET NO. 2-41
 JOB Dam
 SUBJECT Narumbege Res.
 CLIENT Carpi

$$Q_{p1} = 7,448 \text{ cfs} \quad d_1 = 3.9' \checkmark$$

$$Vol_1 = \frac{600 + 1057}{2} \times \frac{400}{43560} = 7.62' \checkmark$$

$$Q_{p2} = 7448 \left(1 - \frac{7.62}{500}\right) = 7,335 \text{ cfs} \quad d_2 = 3.75'$$

$$Vol_2 = \frac{600 + 1043}{2} \times \frac{400}{43560} = 7.54' \quad Vol_{ave} = \frac{7.54 + 7.62}{2} = 7.58'$$

$$Q_{p2} = 7448 \left(1 - \frac{7.58}{500}\right) = 7,335 \text{ cfs}$$

$$Q_{out} = 7,335 \text{ cfs} \quad Elev. = 213.9 \pm'$$

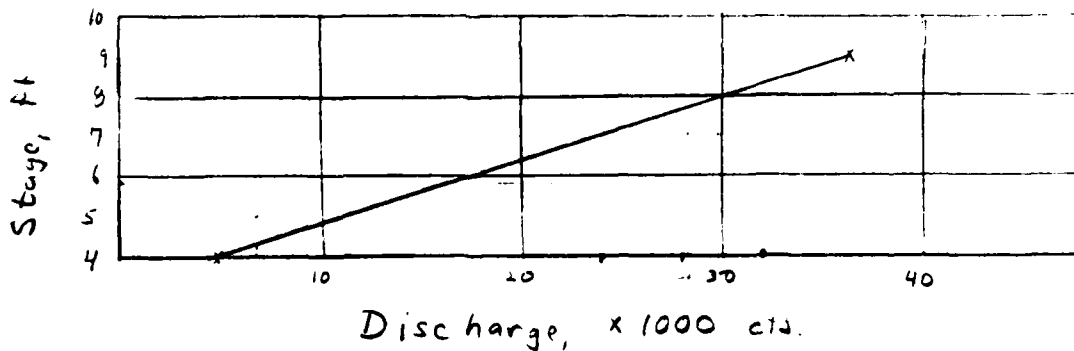
Sta 27+00 - Wellesley Road - Assume any culverts blocked
 (only flow over road).

$$n = 0.06$$

$$S = 0.0143 \quad F' = \frac{1.486}{0.06} \times (0.0143)^{1/2} = 2.96 \checkmark$$

$$V = F' R^{2/3} \quad V = 2.96 R^{2/3}$$

D	WP	A	$R^{2/3}$	F'	V	Q	Elev.
4	500	1000	1.59	2.96	4.71	4706	205.0
9	1000	4500	2.72	"	8.05	36230	210



$$Q_{p1} = 7,335 \text{ cfs} \quad d_1 = 4.3'$$

JOB NO. 79.226.1
 DATE 12.10.79
 BY FJD
 CH'D BY WMA

HH & B HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. 2-42
 JOB Dam
 SUBJECT Narumega Res
 CLIENT Corpi

$$Q_{P1} = 7,335 \quad d_1 = 4.3$$

$$Vol_1 = \frac{1050 + 1140}{2} \times \frac{1100}{43560} = 27.65 \text{ ac. ft}$$

$$Q_{P2} = 7,335 \left(1 - \frac{27.65}{500}\right) = 6,929 \text{ cfs} \quad d_2 = 4.25'$$

$$Vol_2 = \frac{1050 + 1116}{2} \times \frac{1100}{43560} = 27.34 \text{ ac. ft} \quad Vol_{ave} = \frac{27.65 + 27.34}{2} = 27.50 \text{ ac. ft}$$

$$Q_{P3} = 7335 \left(1 - \frac{27.50}{500}\right) = 6932 \text{ cfs}$$

$$Q_{out} = 6,932 \text{ cfs} \quad Elev. = 205.25 \pm'$$

Sta. 32+00

$$n = 0.06$$

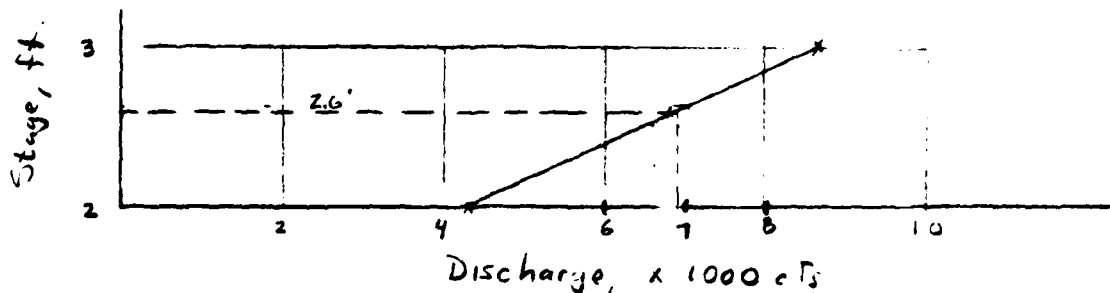
$$S = 0.020$$

$$V = F' R^{2/3}$$

$$F' = \frac{1.486}{0.06} (0.02)^{1/2} = 2.63 \checkmark$$

$$V = 2.63 R^{2/3}$$

$\frac{D}{ft}$	$\frac{WP}{ft}$	$\frac{A}{sf.}$	$\frac{R^{2/3}}$	$\frac{F'}{}$	$\frac{V}{Fps}$	$\frac{Q}{cfs}$	$\frac{Elev.}{M.L.}$
5	700	3000	2.65	2.63 ✓	6.97	20,919	195
3	630	1695	1.94 ✓	"	5.10 ✓	8652 ✓	193
2	580	1080	1.52	"	3.99	4309	192



JOB NO. 79.206.1
DATE 12/10/79
BY FDD
CH'D BY [Signature]



HAYDEN, HARDING & BUCHANAN, INC.
CONSULTING ENGINEERS
BOSTON MASSACHUSETTS

SHEET NO. 2-43
JOB Dams
SUBJECT Norvm arge Res
CLIENT Carps

$$Q_{P_1} = 6932 \text{ cfs. } d_1 = 2.6$$

$$Vol_1 = \frac{1130 + 1480}{2} \times \frac{500}{43,560} = 14.69 \text{ ac-ft}$$

$$Q_{P_2} = 6932 \left(1 - \frac{14.69}{500}\right) = 6728 \text{ cfs. } d_2 = 2.5'$$

$$Vol_2 = \frac{1130 + 1400}{2} \times \frac{500}{43,560} = 14.52 \text{ ac-ft } Vol_{ave} = \frac{14.69 + 14.52}{2} = 14.6$$

$$Q_{P_2} = 6932 \left(1 - \frac{14.6}{500}\right) = 6730 \text{ cfs.}$$

$$Q_{out} = 6,730 \text{ cfs. Elev.} = 192.5 \pm'$$

Water Flows into large swampy area (35± acres)

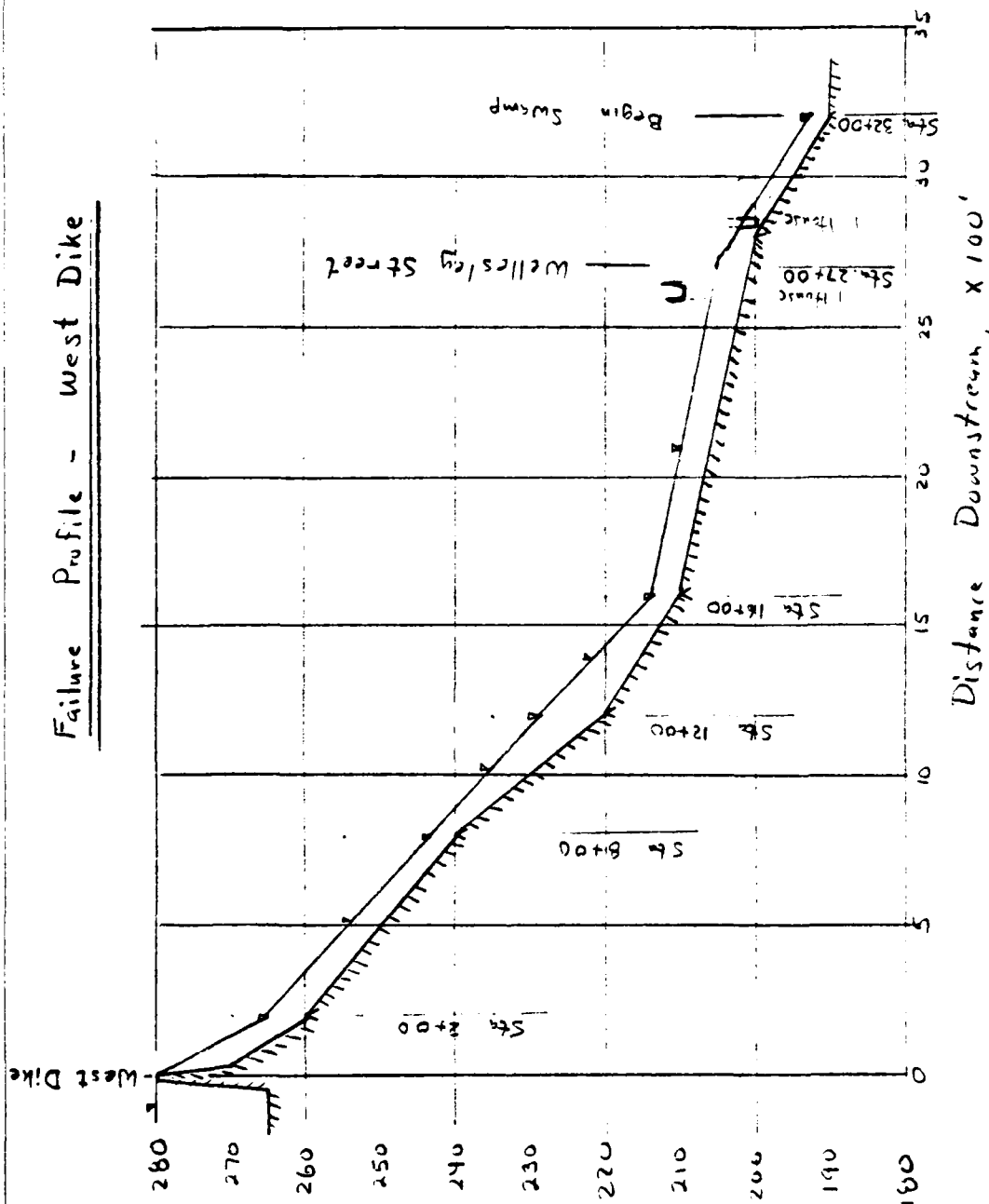
Impact Area: 1 house No[±] flooding (first floor)
Wellesley Rd. overtopped by 4.3'
1 house 4'± flooding

JOB NO. 79.206.1
 DATE 12/10/79
 BY FDD
 CH'D BY WAB



HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. 2-44
 JOB Dams
 SUBJECT Nacumgan Res.
 CLIENT Corps



JOB NO. 79.206.1
 DATE 12/10/79
 BY FDD
 CH'D BY WV

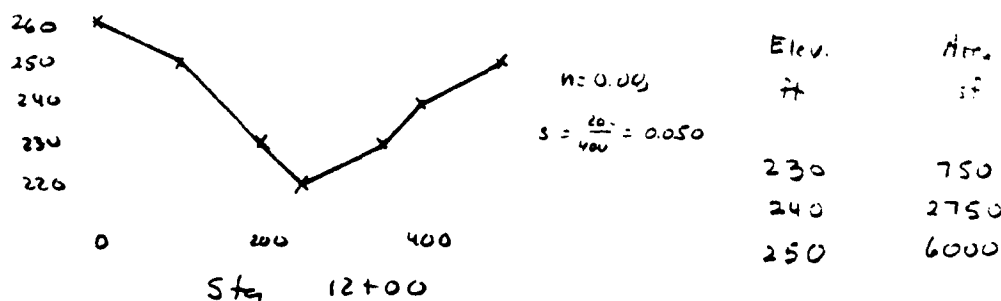
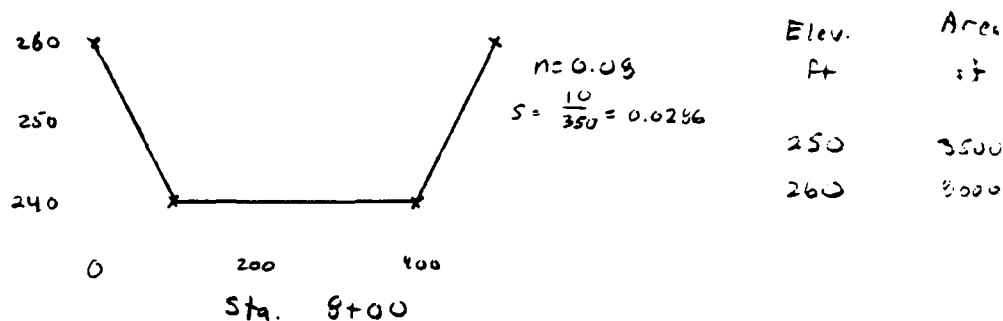
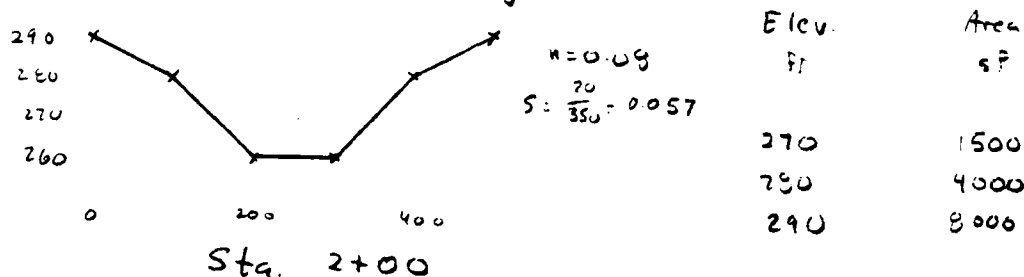


HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

SHEET NO. D-45
 JOB Dams
 SUBJECT Neemega Res
 CLIENT Corps

Cross Sections - Failure of West Dike

Cross Sections looking Downstream



JOB NO. 79.206.1
 DATE 12/10/79
 BY EDD
 CH'D BY WAT

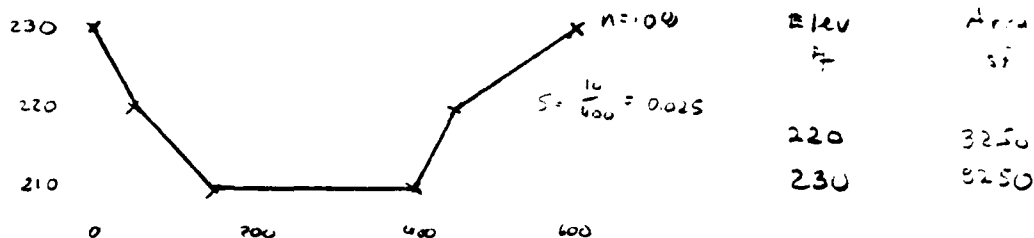


HAYDEN, HARDING & BUCHANAN, INC.
 CONSULTING ENGINEERS
 BOSTON MASSACHUSETTS

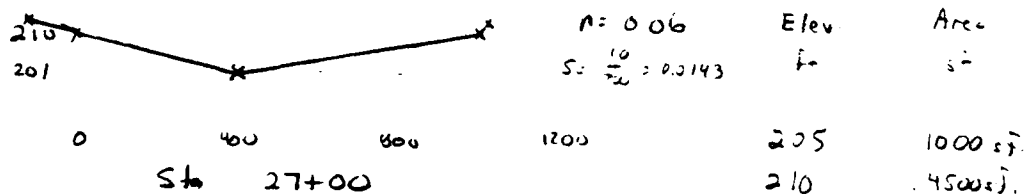
SHEET NO. D-46
 JOB Dams
 SUBJECT Narumbege Res
 CLIENT Csps

Cross Sections - Failure of West Dike

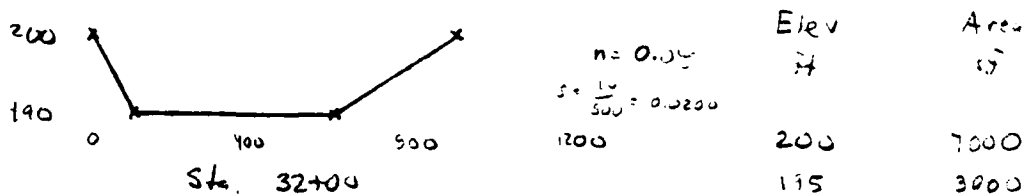
Cross Sections looking Downstream



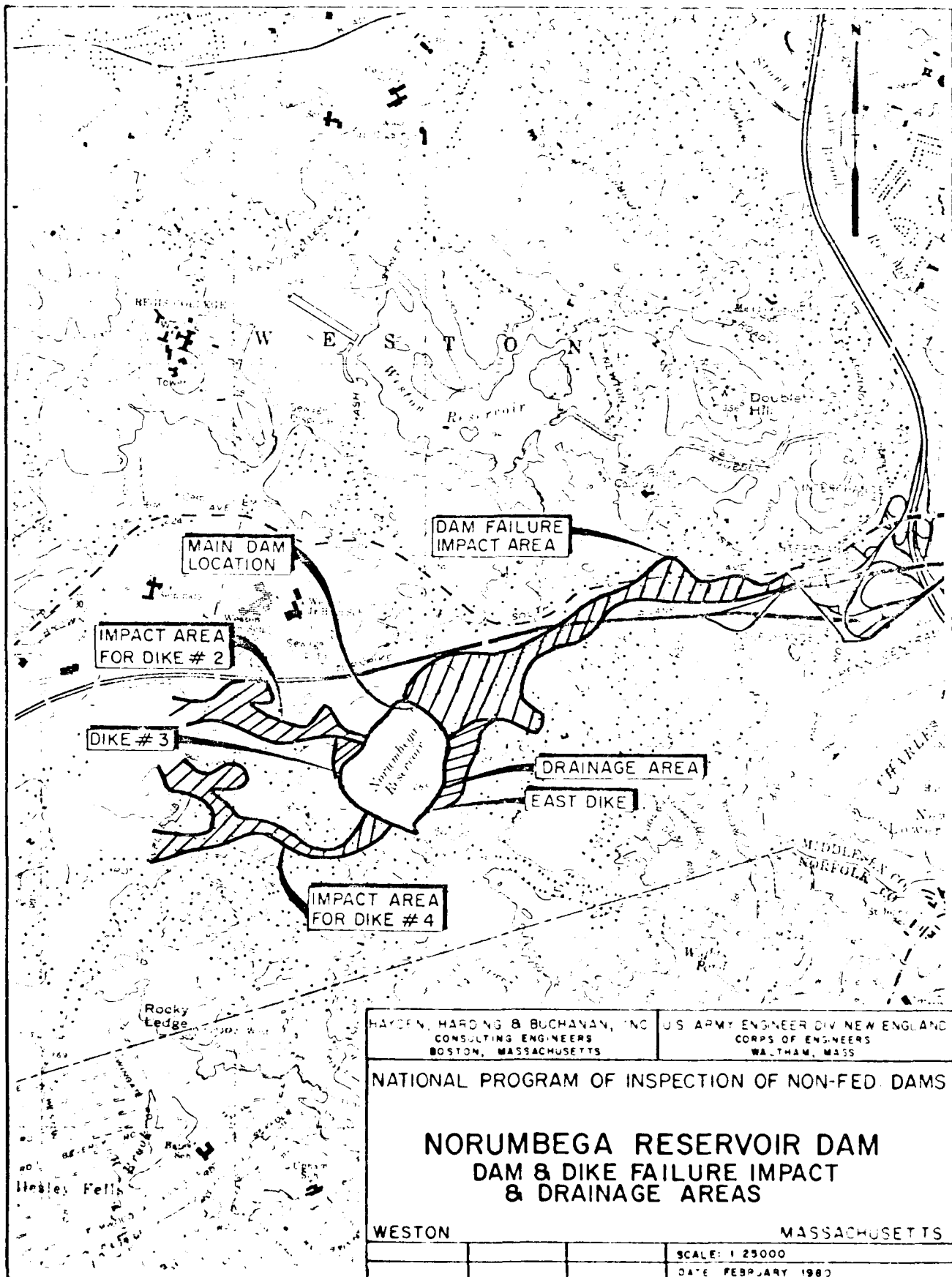
Sta 16+00



Sta 27+00



Sta 32+00



APPENDIX E

INFORMATION AS CONTAINED IN THE
NATIONAL INVENTORY OF DAMS

E-1

Norumbega Reservoir Dam & Dikes

INVENTORY OF DAMS IN THE UNITED STATES

DIVISION		STATE	COUNTY	CROSS	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE
NO.	7-2	NE	MA	017	05			DAY MO YR
					ANDROMEDA RESERVOIR DAM	4220.1	7172.7	15FEB80
					NAME OF EMPLOYMENT			
					ANDROMEDA RESERVOIR			
					NEAREST DOWNSTREAM CITY-TOWN-VILLAGE	POPULATION		
					WESTON	10900		
					TYPE OF DAM	DIST ON FED R		
					CONCRETE	N		
					YEAR COMPLETED	N		
					1970	N		
					PURPOSES	DIST ON FED R		
					HYDROELECTRIC	N		
					IRRIGATION	N		
					NAVIGATION	N		
					RECREATION	N		
					OTHER	N		
					REMARKS			
					1. 1100 FT. LONGEST DIME 10 FT			
					DESIGN	DESIGNER		
					NONE	HAYDEN, HARRING & SICHANAN, INC.		
					CONSTRUCTION	CONSTRUCTION BY		
					NONE	PUBLIC LAR 92-507		
					OPERATION	OPERATION		
					NONE	NONE		
					INSPECTION BY	INSPECTION BY		
					NONE	NONE		
					REMARKS	REMARKS		
					1200 FT LONG EAST DIME			

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INVENTORY OF DAMS IN THE UNITED STATES

STATE	DIVISION	COUNTY	DIST	COUNTY	DIST	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE DAY MO YR
MA	1200 NEL	MA	017	05		NUMUMHEGA RESERVOIR DINE #2 #23	4219.9	7117.9	15 FEB 80

POPULAR NAME		NAME OF IMPROVEMENT	
		NUMUMHEGA RESERVOIR	
REGULATORY	RIVER OR STREAM	NEAREST DOWNSTREAM CITY - TOWN - VILLAGE	POPULATION
01 00	SEVERN'S BROOK	WESTON	0 10900

TYPE OF DAM	YEAR COMPLETED	PURPOSES	HYDROPOWER CAPACITY (KW)	IRRIGATION CAPACITY (ACRES)	INDUSTRIAL CAPACITY (GALLONS PER MIN)	NAVIGATION LOCKS
REG	1940	S	15	15	500	250

REMARKS						
20-DIKE #3 15 FT 25-DIKE #3 15 FT						
U.S. SPILLWAY	MAXIMUM DISCHARGE (CFS)	VOLUME OF DAM (CU YD)	POWER CAPACITY (KW)	INDUSTRIAL CAPACITY (GALLONS PER MIN)	NAVIGATION LOCKS	
1	510	4300				

OWNER	ENGINEERING BY	CONSTRUCTION BY
DESIGN	CONSTRUCTION	OPERATION
NONE	NONE	NONE
INSPECTION BY	INSPECTION DATE DAY MO YR	AUTHORITY FOR INSPECTION
HAYDEN, MARLING & BUCHANAN, INC.	50 OCT 79	PUBLIC LAW 92-347
REMARKS		
30-DIKE #3 500 FT		

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INVENTORY OF DAMS IN THE UNITED STATES

STATE	COUNTY	DIST	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE
MA	1209	05	NORUMBEGA RESERVOIR DIKE #4	4219.7	7117.9	15FEB60

POPULAR NAME	NAME OF IMPOUNDMENT
	NORUMBEGA RESERVOIR
RIVER OR STREAM	NEAREST DOWNSTREAM CITY-TOWN-VILLAGE
SEAVER'S BROOK	WESTON
	DIST FROM DAM (MI)
	0
	POPULATION
	10900

TYPE OF DAM	YEAR COMPLETED	PURPOSES	HEIGHT (FEET)	LENGTH (FEET)	WIDTH (FEET)	SPILLWAY CAPACITY (CU FT)	POWER CAPACITY (KW)	NAVIGATION LOCKS
HEAVY	1940	S	15	15	500	250		

REMARKS

DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NOTE	NOTE	NOTE	NOTE

OWNERSHIP	ENGINEERING BY	CONSTRUCTION BY

INSPECTION BY	INSPECTION DATE	AUTHORITY FOR INSPECTION

REMARKS

MAYDEN, MANDING & MACHANAN, INC. 30 OCT 79 PUBLIC LAW 92-367

DIST OWN FED M PRV/FED SCS A VER/DATE

✓
END

DATE
FILMED

8 - 85

DTIC

END

DATE
FILMED

8 - 85

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